Australian Government
Department of Defence
Defence Science and
Technology Organisation

Future Urban States: a Field Anomaly Relaxation Study

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DSTO-TR-1910

ABSTRACT

The Field Anomaly Relaxation Method (FAR) has been used to derive a set of plausible future urban states. The data was obtained from three two-day workshops involving DSTO staff, military, and academic staff from South Australian universities. An analysis of the results of these workshops identified six key sectors for urban function (each with three generic factors or levels) that could be used to characterise current and future urban environments namely: social behaviour, urban security, governance, societal equity, human and physical welfare and economic prosperity. From this data, 40 possible urban configurations were derived, which were further grouped into 16 scenario clusters. A Faustian Tree was constructed showing possible transitions between the future urban scenarios. The tree clearly broke down into two distinct areas, depending on whether the social behaviour was in a state of tolerant co-existence or intolerant co-existence/societal breakdown. A simple analysis was conducted to evaluate each cluster in terms of urban stability and hence identify urban precincts of interest. The relative probability of different migration pathways between urban states within the Faustian Tree was also investigated. The data generated in this study provides a simple high-level model of the urban environment, with potential applications ranging from urban scenario development (for wargaming) to a study of potential urban evolution (for strategic planning).

Published by

Land Operations Division
DSTO Defence Science and Technology Organisation
PO Box 1500
Edinburgh South Australia 5111 Australia

Telephone: (08) 8259 5555
Fax: (08) 8259 6567

AR 013-732

Submitted: July 2005
Published: August 2006

APPROVED FOR PUBLIC RELEASE

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Executive Summary

The world-wide increase in rural-urban population migration, coupled with the fact that urban precincts are the hub of political, social and economic activity, gives rise to an ever increasing likelihood of urban military operations, especially against unconventional threats. While these aspects of the urban environment contribute significantly to the difficulty of conducting urban operations, in the past they have tended to be considered secondary to conventional military mission success: defeat of a threat. However, many recent operations have demonstrated that, while combat is often still an integral part of the operation, consideration must be given to the role of cities as the centre of a complex functioning society. While contemporary military thinking has acknowledged these issues, there remains the difficulty of how to address this problem. As part of this process, we have identified the need to develop a high-level urban model which focuses on this societal aspect of urban environments.

This paper describes the results of a series of workshops which used a strategic planning technique, Field Anomaly Relaxation (FAR), to identify key urban drivers for change and produce a set of possible future urban states. The drivers were chosen to focus on societal function, rather than physical aspects. From these workshops a set of forty generic urban scenarios was derived which was used to construct a structure showing the possible links between these states known as the Faustian Tree. Potentially unstable or undesirable urban environments are identified, and the derived scenarios are also compared briefly with real world urban environments, although further work is required to validate the model this way. In all three workshops, it appears that the scenarios fall into two groups characterised by tolerant/peaceful or intolerant/violent social behaviour, and while transitions within each group were numerous, transitions between the two groups were less common and/or involved simultaneous transitions in several drivers.

The final set of six sectors (social behaviour, urban security, governance, societal equity, human and physical welfare and economic prosperity) and their underlying factors appear adequate for the generation of plausible urban scenarios and for investigating potential evolution between them, so that pathways from undesirable to desirable urban environments can be studied. However, this analysis only allowed for incremental change between scenarios, whereas in real life, dramatic changes could occur, as a result of war or natural disaster, which was not explicitly covered by this model. In addition, it may be necessary to develop higher-resolution models that are more appropriate for particular cities or regions of interest, for example those likely to exhibit unstable social behaviour or poor levels of security or governance.

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1. Introduction

It is generally accepted within the defence community that the worldwide likelihood of urban military operations is increasing. There are many recent examples where urban precincts are key focal points inherently linked to strategic centres of gravity. Campaigns in Chechnya, Somalia and more recently Iraq and Afghanistan have demonstrated the critical nature of controlling towns and cities.

There appear to be two key reasons behind this observation. Firstly, demographic trends indicate that populations continue to migrate from rural to urban centres, and since urban precincts are focal points for economic, political and social activity, they are prime targets for forces attempting to influence national decision makers. Secondly, potential adversaries are aware that the many technological advantages possessed by modern military forces on the open battlefield are at least partly neutralised in cities and towns. The natural clutter and uncertainty created by such environments, particularly when occupied by non-combatants, creates a number of dilemmas for even the most capable force. The urban environment has therefore become an increasingly attractive proposition for non-conventional threats. This is exemplified by the difficulties coalition forces (and those of the new Iraqi Government) have had dealing with the ongoing insurgency in Iraq, which operates almost exclusively in urban areas and whose success results from the difficulties imposed by the urban environment.[1]

While a significant component of an Urban Military Operation will focus on military mission success, there are other issues that this approach ignores. Cities are the hub of societies, where societal function will continue to occur in some form, regardless of the presence of military activity. Indeed the military presence may impinge on this everyday urban function and hence may impact negatively on the success of the operation. This may be true even when the military presence is there to try and restore (or improve) societal normality. This could be through the defeat of a threat (e.g. as part of a regional war or counter-insurgency) which was impacting negatively on the urban environment, and also less combat-centric activities such as peace enforcement/peacekeeping. In some cases the 'normal' conditions of the particular city may have been the drivers for the situation demanding the military presence (e.g. the breakdown of law and order in the Solomon Islands that precipitated Operation Anode). In summary, even though the military operation may aspire to help the urban population, ultimately the population may not respond favourably unless those conditions which define an acceptable level of urban function are achieved.[2]

In order to consider this effect, some measure of what characterises and drives the function of urban societies is necessary; what constitutes a desirable (or at least acceptable) state of urban function and what is undesirable (and hence may impact negatively on the

[1] A report of an assessment by the Central Intelligence Agency says Iraq may prove to be an even more effective training ground for Islamic extremists than Afghanistan was in Al Qaeda's early days, because it is serving as a real-world laboratory for urban combat [1].

[2] This is illustrated by the evaporation of good-will towards the US that immediately followed the overthrow of Saddam Hussein, as the failure to restore basic services such as power and water and the death of civilians was blamed on US forces. This is a separate issue to the insurgency.

operation or be the reason for it). Under Task ARM 03/102, Urban Operations Studies in the Regional Littoral, we have been looking at ways in which to characterise and describe various aspects of the urban environment. A recent report under this task looked at the issues of demographics, culture and infrastructure for urban environments in the Australian (AS) region [2]. We have also conducted a number of historical analyses of population reactions in several countries in the AS region [3-4]. This work has helped increase our understanding of many of the issues confronting those conducting urban operations. However they do not entirely address the issues identified in the previous paragraph, and we have identified two areas which still need to be considered. Firstly, we require a generic higher-level model or analytical framework of the urban environment, which is applicable to a range of (if not all) urban environments and which looks at the problem of defining urban societal function. Secondly we need to know about the likely evolution of these areas, in order to assist in strategic planning for urban operations.

A technique which would be ideally suited to this requirement is that of Field Anomaly Relaxation (FAR). In this paper, we present the results of three workshops conducted during 2004 using the FAR technique to create a set of possible future urban states.[3] We also use the results of these workshops to derive a simple generic analytical framework to describe the urban environment in terms of sectors, which relate to the physical, political, cultural, societal, economic and security aspects of the urban environment. This framework can be used to generate plausible urban scenarios, and to map out possible evolutionary pathways between them. In particular, it allows us to identify potential urban trouble spots, and examine the migration to and from these states.

2. Urban Operations- Strategic Aims

The need for a strategic level urban model, and the shape it needs to take, are further explored in the following section. As discussed above, cities have strategic significance and any urban operation should contribute to some overall strategic goal, which will be more than just defeating the enemy. While the operation conducted by the ADF may range from emergency relief (as exemplified in Aceh) to the defeat of a threat, the aspirational strategic outcome will be to try and ensure the urban centre ends up in a state that is acceptable to the AS Government.[4] For Australia, some indication of what this strategic goal might be can be gained from consideration of the Defence White paper [5]:

1. *'Our second strategic objective is to foster the security of our immediate neighbourhood. We would be concerned about internal challenges to the stability and cohesion of neighbouring countries and concerned about any threat of external aggression against them.*

[3] LOD contracted the services of Professor Charles Newton, Emeritus Professor at the University of New South Wales/Australian Defence Force Academy to help organise and facilitate these workshops. See Appendix A for details.

[4] This will not always be the same as what is acceptable to, or desired by, the populace of that urban centre, or the authorities running it, simply because in most cases, this will beyond our capability to achieve; for example AS could not completely rebuild all the infrastructure destroyed in all the countries affected by the Boxing Day Tsunami. However, an urban operation that facilitates an outcome that is desired by the populace will greatly increase the chance of success.

2. *Our third strategic objective is to work with others to promote stability and cooperation in Southeast Asia. Our key strategic interest in Southeast Asia is to maintain a resilient regional community that can cooperate to prevent the intrusion of potentially hostile external powers and resolve peacefully any problems that may arise between countries in the region.*

3. *Our fourth strategic objective is to contribute in appropriate ways to maintaining strategic stability in the wider Asia Pacific region. We would want to avoid the emergence in the Asia Pacific region of a security environment dominated by any powers whose strategic interests might be inimical to Australia's and to avoid destabilising competition between the region's major powers.'*

The clear thrust of these statements is about regional stability, both in our immediate neighbourhood and in the wider Asia Pacific Region. Given that urban precincts are focal points for economic, political and social activity, this requirement for regional stability may reasonably be translated into a requirement for stable urban centres (especially for capital cities). Thus, it is clear that the evolution of urban environments is highly important, both in our immediate region of strategic interest, but also worldwide, with a trend towards increasing stability being desirable (in most cases), and a trend towards instability being undesirable from the AS strategic perspective.

From this argument, it is clear that our urban model needs to emphasise stability, essentially social stability or the behaviour of the population in that environment. This observation agrees with our earlier assertion about the need for urban precincts to attain an acceptable state of urban function, which will tend to be a driver for stability.[5] Consequently, while participants in the workshops were not constrained in their consideration of urban environments, it was made clear that they needed to consider these issues.

3. FAR Workshops

3.1 The FAR Method

The Field Anomaly Relaxation Method [6-7] is a tool used for strategic analysis and planning which allows the development of a range of plausible future scenarios and an understanding of how they may evolve. A detailed description of the FAR method is given in Appendix A. While FAR is often (but not exclusively) used to predict high level or global states, prior to this work the application of FAR to the determination of urban states was deemed plausible. The results of this study demonstrate that FAR did indeed prove its utility in examining urban environments. Examples of previous studies using FAR include the following:

[5] However, factors leading to war or insurgency may not necessarily result directly from the population's reaction to an unacceptable state of the urban environment as in principle, any actor or group could instigate conflict, regardless of social conditions.

- Strategic Planning for Special Forces [8].
- Cultural Perspectives on the AS Regional Strategic Environment [9]
- Sociopolitical Context for the Nations of the South China Sea [10]
- Resource Management [11]

3.2 Workshop Method

Some weeks prior to the workshops, the participants were supplied with a brief explaining the FAR process, and the aim and scope of the work (see Appendix A). At the start of each workshop, the participants also received a presentation from the facilitator and sponsor, in order to reinforce and clarify the ideas presented in the pre-workshop brief. Participants were also shown the use of the group-storming hardware and software (see A.2).

In all three workshops, participants completed the first 5 sessions listed in section A.4. (i.e. up to and including the pairwise comparison of the factors/sectors to remove all the perceived anomalies). The sixth session was intended to look at clustering the remaining futures into a manageable set to allow the construction of a Faustian Tree. This stage was not reached in any of the workshops, as the groups ran out of time. However, this aspect was not as important as the previous stages, and sufficient data was collected to allow the construction of the Faustian Tree at a later stage (see section 4).

3.3 Workshop Results

3.3.1 Workshop 1

The sectors and factors pertaining to urban environments and their futures derived in this workshop appear in Table 1. The sector definitions appear in Table 2. The symbolic acronym chosen by this group was SEXIDUC. The group reached a consensus that the set of factors that could describe a present South East Asian city was: S2E2X3I3D3U3C2, corresponding to:

Social Infrastructure: Rudimentary
Environmental factors: Habitable
Societal Expectation: Accepting
Physical Infrastructure: Basic
Economic Development: Growth - Unequal
Urban Behaviour: Tolerated
Cultural Aspects: Intolerant- possible clashes

The pairwise comparison of the derived factors left over 1500 possible urban environments, which is an unmanageable number. However, there was insufficient time to reduce this number by clustering (see Appendix A) similar factors as time had run out.

This workshop progressed very slowly, as there was significant discussion on exactly how to describe an urban environment and whether the focus should be on human and demographic factors or on physical factors. This problem recurred consistently through the workshop but was useful in preparation for the subsequent workshops, in that the

focus was directed early on towards societal factors rather than at the physical characteristics of the urban environment.

An examination of the sectors and factors in Table 1 reveals a commonality with the STEEPV[6] set of sectors often used in brainstorming foresight sessions [12]. There were however, a number of differences, some of which arose from the focus on the urban environment. Political aspects and security were included in the social infrastructure. There is no sector explicitly corresponding to technology; however there would be some degree of correlation between the level of technology and the physical and social infrastructure. However, a society could have a well-developed social and physical infrastructure, without being considered technologically advanced (e.g. ancient Rome). Economy is covered by both Environmental Factors (level of natural resources) and Economic Development; however the latter looks at the distribution of wealth as well as the absolute value. A key sector identified in this workshop is Societal Expectation, which would be a strong driver for social behaviour, and also linked to many of the other sectors. The sector Urban Behaviour indicates the importance this group attached to external opinion and influences. At one extreme, a Shining Example is likely to have a high moral standing and open trade and commerce. A Poorly Regarded urban environment is likely to be completely ignored by the outside world, or may even be subject to sanctions. In this regard, there may be no difference between the city and the country it is located within.

3.3.2 Workshop 2

The sectors and factors pertaining to urban environments and their futures derived in this workshop appear in Table 3, with the sector definitions in Table 4. The symbolic acronym chosen by this group was GWASPED. The group reached a consensus that the set of factors that would best describe a present Western city (such as Adelaide) was: G2W1A2S1P1E2D1, corresponding to:

Governance: Representative
Welfare: Exceptional
Awareness: Broad awareness
Security: Peaceful
Prosperity: 1st World Affluent
Equity: Inequity but accepted (content with lot)
Diversity: Monocultural

During the pairwise comparison, it was realised that this number of factors would lead to a very high number of scenarios, so it was agreed to reduce the number of factors, in particular those under the Diversity and Awareness sectors. These became:

Diversity: Multicultural and tolerant
Monocultural
Multicultural and intolerant

[6] The STEEPV approach is a planning method similar to FAR, but where sets of future scenarios are derived from a pre-defined set of dimensions (Social, Technological, Economic, Environmental/ Ecological, Political, and Values).

Awareness: Deep Awareness
Broad Awareness
Limited Awareness

The pairwise comparison of the new group of factors still led to several thousand scenarios, necessitating the following clustering to be carried out by the group:

G3 + G4 Guided Democracy and Accepted Democracy
W3 + W4 Inadequate and Non-existent Welfare
S1 + S2 Peaceful and Controlled Security
P1 + P2 1st World Affluent and 2nd World Emerging Prosperity

This lead to a significant reduction in scenarios, with 772 clustered scenarios remaining after the pairwise comparison. No further grouping was possible in the time available. This workshop also progressed rather slowly, with significant discussion on the most appropriate sectors to describe an urban environment. In this case, the lessons learned from the first workshop directed the initial focus on the human aspects of the urban environment, rather than the physical ones. As a consequence, the set of sectors for this workshop is richer in societal issues than the first workshop.

The sectors derived in this workshop are similar to those from Workshop 1; however Governance and Security appear as separate sectors. The factors of Governance are based on the mode of regulation (e.g. democratic) rather than the level of effectiveness. In contrast, security was based on people's perception of their own safety, rather than the level of security forces or mode of control. Prosperity covers both the degree of wealth and the quality of infrastructure; the factors under this sector are based on somewhat western perceptions, with 1st World Affluent being assigned as the best factor. Equity is similar to Societal Expectation, in that it measures people's perception of whether they are getting a fair go. An additional sector, Awareness (of the world beyond the community) is also an important social driver; for example deeply aware societies may be less susceptible to manipulation (e.g. through the rhetoric of a highly authoritarian government). It will be linked to education but is not the same; people may be highly educated but not necessarily deeply aware, although they are more likely to be so. The sector Welfare relates to social infrastructure but goes beyond; it is not just the existence of health and education systems, but also the provision of such services to the disadvantaged. Thus, there would still be many Western cities in which the welfare could not be considered exceptional.

3.3.3 Workshop 3

The sectors and factors pertaining to urban environments and their futures derived in this workshop appear in Table 5. The sector definitions appear in Table 6. The symbolic acronym chosen by this group was GOSIPE. The group reached a consensus that the set of factors that could describe a present city in South East Asia or the South West Pacific was: G2O2S4I2P5E3, corresponding to:

Governance: Partially Functional
Society: Pluralistic Unstable
Security: Fragmented
Infrastructure and Environment: Megacity

Population: Dynamic - Segregated
Economy: Weak

The factors shown in Table 5 give rise to more than a thousand scenarios. This problem was tackled by progressively clustering more and more factors and monitoring the resultant number of scenarios. The following list ended up reducing the total number of scenarios to 95. At this point, the workshop concluded.

G3 + G4	Competent and Fully Functional Governance
O3 + O4	Homogeneous – Stable and Homogeneous – Unstable Society[7]
S4 + S5	Fragmented and Ineffective Security
I3 + I4	Regional City and Town (Infrastructure and Environment)
P1 + P2	Stagnant – Segregated and Stagnant Mixed Population
P3 + P4	Slow Growth – Segregated and Slow Growth – Mixed Population
P5 + P6	Dynamic – Segregated and Dynamic – Mixed Population
E1 + E2	Strong and Sound Economy
E3 + E4	Weak and Stagnant Economy

The results of this workshop were of particular interest as five of the participating members were from various departments of Flinders University and the University of South Australia, selected to provide subject matter expertise (see Appendix B). Their contribution to the study was important in lending credibility to the final set of sectors and factors derived. A comparison of the results from all three workshops shows that the three groups in fact came up with sectors and factors that were not significantly different (see 4).

As with Workshop 2, Governance and Security are identified as of high importance and warrant their own sector. The infrastructure and environment were included in the same sector, as it was believed that the highest quality of infrastructure must include good environmental management (thus many cities will have well developed physical infrastructure but significant environmental degradation and pollution). For this sector, existing types of urban environments were used to provide the factors, with Modern Metropolis corresponding to a city such as Singapore and the Megacity corresponding to the usual understanding of that term (e.g. Jakarta). The other sectors utilised generic factors (see section 3.4.2). Unlike the other workshops, it was considered important to include a demographic sector Population, to account for both the population growth and the settlement pattern (segregated or mixed). Interestingly, security warranted five factors. Excessive security would be effective, but brutal. Destabilising security would interfere with/be contrary to the regulations of governance, and fragmented security would consist of various forms of security; e.g. military, police and private security all operating concurrently (but not necessarily cooperatively). It was noted that private security firms were becoming increasingly significant in urban societies.

[7] This clustering was decided upon by the group. In the opinion of the author, a better combination of factors would have been O1 + O3 and O2 + O4, i.e. combining the stable and unstable factors under the Society sector. However, the software only allowed the combination of factors adjacent in the sector matrix, which precluded these actions without re-entering all the data.

3.4 Common Issues Arising from the Three Workshops

The advantages and disadvantages of the FAR process have been detailed in a number of works. The issues that arose from this series of workshops are discussed below.

3.4.1 Level of Detail

The FAR process takes many ideas from the brainstorming sessions and looks for common themes to generate sectors and factors. In doing so, an analytical framework is generated, with the loss of some of the original detail. Partly, this arises from the need to condense a series of narrative statements into one or two word sectors and their underlying factors. Secondly, when generating the possible scenarios from these factors (a scenario consists of one factor from each sector), the number of sectors and factors must be kept to a reasonable level to remain manageable. Thus, a number of sectors derived earlier in the process may be discarded when arriving at the final set of sectors and factors. Another problem that arises is the combination of too many ideas into a sector, with the result that the sector is really a combination of several distinct areas. An example of this comes from the Population sector of Workshop 3, which was defined as the size, structure, composition, growth and dynamics of a population, and its settlement pattern. This definition includes several ideas that could be considered as separate sectors and probably arose from an unwillingness of the group to discard information they felt was important in defining the urban environment.

Fortunately, this loss of detail is less of a problem than might be imagined. Some of the original detail is captured in the sector definitions. In addition, many potential sectors are what can be described as orthogonal. Orthogonal sectors are those which can co-exist with any of the other sectors.[8] An example could include the underlying terrain of the urban environment (e.g. mountainous, flat, rivers etc.). This would be an important aspect of the appearance of the urban centre, and affect the city layout and development patterns (which themselves could also be orthogonal sectors), but these factors could readily co-exist with all the other sectors, especially the societal ones.

The net result of such orthogonal sectors (and factors) is that when a scenario is derived from the factors of the existing sectors, then additional detail can be added to the scenario using these orthogonal sectors without the need for any further analysis. In addition, any previously discarded sectors could be included in a 'mini-FAR' exercise, in which the factors of the final set of sectors are fixed, giving combinations (scenarios) that are of particular interest. The mini-FAR session would then involve a new pairwise comparison between the fixed factors and the additional ones, followed by the derivation of a new, more detailed set of scenarios. Thus, the raw data from the brainstorming sessions should be retained for future reference.

The factors under each sector must also be considered an average across the entire urban environment. In many cities, there will be a great variability in many of the sectors; for example some areas will have fully effective security, fully developed infrastructure and

[8] In terms of the pairwise comparison (see Appendix A) each factor of an orthogonal sector would have a Y when compared with the factors of the sectors to which it was orthogonal. That is, there would be no relaxation of anomalies.

great wealth, whereas others will be the complete opposite. Thus, the factors describe an average situation. For example, a city such as Sydney has some low socio-economic areas but on the whole should be characterised by the 'best-case' factors under each sector. Cities with both examples of great wealth but also widespread poverty and sub-standard housing would probably be described by 'middle-case' factors (e.g. a weak rather than strong or subsistence economy, and developing rather than fully-developed or non-existent infrastructure).

3.4.2 Generic Factors

The derivation of generic factors was a key outcome of this study, and was observed in many cases for all three workshops. Generic factors look at the 'what' aspect of the sector, rather than the 'how' or 'why'. For example, in Workshop 3, it was concluded that the key factor for governance was competence, rather than whether the government was labelled authoritarian or democratic (specific factors of governance). This is reflected in the factors of governance presented in Table 6. Similarly, the sectors for social behaviour focussed on whether or not there was social stability, rather than looking at the reasons for this (i.e. whether the differences were due to religion, ethnicity or other reasons). Using generic factors also ensured that the full range of possible factors from best-case to worst-case was encompassed for each sector, which makes clustering easier and allows better comparison between scenarios. Generic factors are also better suited to describing future scenarios as well as present ones; specific factors are based on current and past scenarios. Generic factors were not derived for all sectors in the three workshops but were used when the results of the three workshops were combined (see section 4).

3.4.3 Transient Factors

There is some ambiguity between what a factor is and what a transient or transitioning factor is. One factor could slowly transition to another over the course of thirty years (e.g. a slowly declining economy due to exhausted natural resources) or change rapidly in the space of a few months (e.g. due to a war or natural disaster). A weak economy could remain weak, or change to either an affluent or subsistence economy. In this study, the sectors and factors pertain to a 'snapshot' of the situation; the mechanism by which factors transition is a separate issue.

3.4.4 Urban vs National Situation

Many of the sectors and factors derived in this study could just as easily pertain to the nation within which the urban environment resides. It was necessary to keep the workshops focussed on the city/town, as the study was interested in all urban precincts within a given nation, which would include the capital city and seat of government, but also minor towns, which could be far removed from the national picture.

3.4.5 External Influences

This issue also relates to the national one above. External influences may be quite important in defining an urban environment. Capital cities may receive a greater share of the national wealth, and have better infrastructure and employment opportunities than regional urban centres. Conversely, towns with poor natural resources situated in a hostile

natural environment may nevertheless function well due to the quality of the national infrastructure, governance and economy. In addition, factors external to the country (e.g. war, foreign aid, economic sanctions) may influence the functioning of a particular urban environment in the same way they do the country. While important, these issues were considered to be excessive detail, and beyond the scope of the generic factors used in the final analysis. They could be included using a mini-FAR session as described in section 3.4.1.

3.4.6 Western Perspective

Many of the participants were of Western European/Australian origin, who had spent most, if not all of their lives in Australia. Consequently, it was felt that there was a danger of imposing Western perceptions on what was supposed to be a global environment. For example, it was generally felt that an urban environment could not be considered totally secure without a widespread, fully functional institutionalised security force (assuming the absence of a utopian crime-free society). However, in Workshop 3 it was noted that people in Indonesian urban centres felt safe, despite the absence of a fully functional security system. Thus, the question arises as to whether the urban environment should be described from the perceptions of those living within it, or from an external (western) perspective. It was concluded that the latter would be preferable as it was necessary to have a consistent reference point, provided that the possibility of bias was taken into consideration.

Table 1. Urban sectors and factors from Workshop 1

	Sectors						
Factors	Social Infrastructure	Environmental Factors	Societal Expectation	Physical Infrastructure	Economic Development	Urban Behaviour	Social Behaviour
	S1 Ordered	E1 Spare Capacity	X1 Satisfied	I1 Well developed	D1 Booming Economy	U1 Shining Behaviour	C1 Integrated Peaceful
	S2 Rudimentary	E2 Habitable	X2 Demanding	I2 Developing	D2 Growth-Equal	U2 Respected	C2 Tolerant Differences
	S3 Dysfunctional	E3 Bouts of Uninhabitability	X3 Accepting	I3 Basic	D3 Growth-Unequal	U3 Tolerated	C3 Intolerant, Possible Clashes
	S4 Failed	E4 Uninhabitable	X4 Apathy	I4 Undeveloped	D4 Stagnation	U4 Poorly Regarded	C4 Violent- Differences Lead to Clashes
					D5 Dysfunctional		

Table 2. Sector definitions from Workshop 1

Sector	Definition
Social Infrastructure	The institutional framework that allows the urban society to function; includes government, security, health and education.
Environmental Factors	The environmental factors, such as natural resources, pollution and climate that influence the running of the physical infrastructure affecting the health of the urban population and their standards of living.
Societal Expectation	People's perceptions of what they want, in the context of what the urban environment provides.
Physical Infrastructure	The tangible aspects of an urban environment within which the human interacts, which include: development and enforcement of laws, regulations and rules, physical components of urban development, and natural geographic factors that influence development.
Economic Development	The wealth and its distribution within the urban environment.
Urban Behaviour	The performance of the urban environment as influenced by or judged from an external point of view.
Social Behaviour	The diversity of factors such as ethnicity, religion, beliefs, language and values, that influence peoples behaviour and the way the society functions.

Table 3. Urban sectors and factors from Workshop 2

	Sectors						
	Governance	**W**elfare	**A**wareness	**S**ecurity	**P**rosperity	**E**quity	**D**iversity
Factors	G1 Anarchy	W1 Exceptional	A1 Deep	S1 Peaceful	P1 1st World Affluent	E1 Perceived Equity	D1 Monocultural
	G2 Representative	W2 Adequate	A2 Broad	S2 Controlled	P2 2nd World Emerging	E2 Inequity but accepted (content with lot)	D2 Bicultural and tolerant
	G3 Guided Democracy	W3 Inadequate	A3 Limited	S3 Unstable	P3 3rd World Subsistence	E3 Inequity but not accepted	D3 Bicultural and intolerant
	G4 Accepted Autocracy	W4 Non-existent	A4 Rudimentary	S4 Unsafe	P4 3rd World Crisis-Impoverished	E4 Extreme Inequity (Discriminatory)	D4 Multicultural and tolerant
	G5 Totalitarianism			S5 Life Threatening			D5 Multicultural and intolerant

Table 4. Sector definitions from Workshop 2

Sector	Definition
Governance	Modes of regulation and control for shaping the behaviour of community.
Welfare	The identification and targeting of help to disadvantaged individuals or groups through provision of organised programs.
Awareness	Level of understanding of the world beyond the community.
Security	The community's perception of threat to their personal safety.
Prosperity	The wealth and quality of infrastructure of a community.
Equity	A sense of fairness relative to the wider community.
Diversity	The presence of a variety of cultures and ideologies, and their interaction.

Table 5. Urban sectors and factors from Workshop 3

	Sectors					
Factors	**G**overnance	S**o**ciety	**S**ecurity	**I**nfrastructure and Environment	**P**opulation	**E**conomy
	G1 Dysfunctional G2 Partially Functional G3 Competent G4 Fully Functional	O1 Pluralistic- stable O2 Pluralistic- unstable O3 Homogeneous- stable O4 Homogeneous- unstable	S1 Sound S2 Excessive S3 Destabilising S4 Fragmented S5 Ineffective	I1 Modern Metropolis I2 Megacity I3 Regional City I4 Town	P1 Stagnant- segregated P2 Stagnant- mixed P3 Slow growth- segregated P4 Slow growth- mixed P5 Dynamic- segregated P6 Dynamic- mixed	E1 Strong E2 Sound E3 Weak E4 Stagnant

Table 6. Sector definitions from Workshop 3

Sector	Definition
Governance	The political, administrative and legal systems used to organise, control, direct and manage the city.
Society	The character of the social structures (ethnicity, gender, religion and class) and the corresponding behaviours and value systems that support them.
Security	Safeguarding society from any threats to the individual and collective well-being.
Infrastructure and Environment	The quality of the overall infrastructure and the characteristics of the supporting environment.
Population	The size, structure, composition, growth and dynamics of a population and its settlement pattern.
Economy	The production and distribution of wealth (including goods and services) in society and its influence on the functioning of other societal institutions.

4. Analysis

4.1 Development of Faustian Trees

The Faustian Tree (see Appendix A) is a tree-like structure that shows the possible evolution of future scenarios and the transitions between factors that give rise to these changes. The following sections describe further work involving clustering similar factors and other simplifications, which allowed the reduction of the number of configurations to a more manageable level and the generation of Faustian Trees for Workshops 1 and 3. For Workshop 2, after clustering there still remained more than 100 configurations and these results were not pursued further.

4.1.1 Workshop 1

In order to develop some experience in the development of Faustian Trees, and to get an initial feel for how this structure might appear for the evolution of future urban states, a much-simplified set of sectors and factors was derived from those appearing in Table 1. In order to achieve a small (easily manageable) number of configurations, the resolution was limited to only two or three factors per sector. The revised sectors and factors are presented in Table 7. The pairwise comparison for this new set of data, is presented in Table 8, where anomalous pairs of factors are indicated by 'N' and factors than can co-exist are represented by 'Y'. The relaxing of these anomalous pairs resulted in 29 unique configurations, which are shown in Table 9.

Table 7. Simplified set of sectors and factors derived from Workshop 1

	Sectors						
Factors	**S**ocial Infrastructure	**E**nvironmental Factors	Societal E**x**pectation	Physical **I**nfrastructure	Economic **D**evelopment	**U**rban Behaviour	So**c**ial Behaviour
	S1 Ordered	E1 Spare Capacity	X1 Satisfied	I1 Well developed	D1 Growth-Equal	U2 Respected	C1 Peaceful-Integrated or Tolerant Differences
	S2 Rudimentary	E2 Habitable	X2 Not-satisfied	I2 Developing	D2 Growth-Unequal	U2 Poorly Regarded	C2 Intolerant, Possible Clashes or Violence
	S3 Dysfunctional	E3 Barely Habitable		I3 Basic	D3 Stagnation		

In previous work using FAR, there was significant group participation in developing the Faustian Tree. Ideally, participants should spend a sufficient amount of time giving consideration to how future scenarios might evolve. There are a number of approaches that can be taken when developing a Faustian Tree. In the earliest work using FAR, participants simply drew the configurations on a wall. More recently, the Faustian tree has been developed by choosing a starting state (present situation) and assigning probabilities for transitions between factors under each sector. Additional configurations can be added manually to the tree, providing the transition probability exceeds some agreed upon

threshold. This approach also requires significant work on the part of the participants, in order to assign plausible transition probabilities. Although more sophisticated means are now available, drawing out the tree by hand is a good starting point to understanding the structure as it evolves; all Faustian Trees in this study were drawn by hand prior to using electronic means. The software used in the FAR workshops can also be used to build the tree automatically from this data; a threshold transition probability is chosen and all configurations are drawn which can be reached from the present situation providing the cumulative transition probability exceeds the threshold.

Table 8. Pairwise comparison matrix for data presented in Table 7. – Y indicates that the factors can co-exist, N indicates that the factors are anomalous.

	E1	E2	E3	X1	X2	I1	I2	I3	D1	D2	D3	U1	U2	C1	C2
S1	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y
S2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
S3	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	N	Y	N	Y
E1				Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
E2				Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
E3				N	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y
X1						Y	Y	N	Y	N	N	Y	N	Y	N
X2						Y	Y	Y	Y	Y	Y	N	Y	N	Y
I1									Y	Y	N	Y	Y	Y	Y
I2									Y	Y	N	Y	Y	Y	Y
I3									N	Y	Y	N	Y	N	Y
D1												Y	Y	Y	N
D2												N	Y	Y	Y
D3												N	Y	Y	Y
U1														Y	N
U2														Y	Y

Table 9. Scenario configurations derived from the sectors and factors in Table 7

Configuration No.	Configuration	Configuration No.	Configuration
1	S1E1X1I1D1U1C1	16	S2E2X1I2D1U1C1
2	S1E1X1I2D1U1C1	17	S2E2X2I1D2U2C2
3	S1E1X2I1D2U2C2	18	S2E2X2I2D2U2C2
4	S1E1X2I2D2U2C2	19	S2E2X2I3D2U2C2
5	S1E2X1I1D1U1C1	20	S2E2X2I3D3U2C2
6	S1E2X1I2D1U1C1	21	S2E3X2I2D2U2C2
7	S1E2X2I1D2U2C2	22	S2E3X2I3D2U2C2
8	S1E2X2I2D2U2C2	23	S2E3X2I3D3U2C2
9	S2E1X1I1D1U1C1	24	S3E1X2I3D2U2C2
10	S2E1X1I2D1U1C1	25	S3E1X2I3D3U2C2
11	S2E1X2I1D2U2C2	26	S3E2X2I3D2U2C2
12	S2E1X2I2D2U2C2	27	S3E2X2I3D3U2C2
13	S2E1X2I3D2U2C2	28	S3E3X2I3D2U2C2
14	S2E1X2I3D3U2C2	29	S3E3X2I3D3U2C2
15	S2E2X1I1D1U1C1		

Table 10.The eight $X_{12}U_{12}C_{12}$ transitions.

Configuration No.	From Configuration	Configuration No.	To Configuration
1	S1E1X1I1D1U1C1	3	S1E1X2I1D2U2C2
2	S1E1X1I2D1U1C1	4	S1E1X2I2D2U2C2
5	S1E2X1I1D1U1C1	7	S1E2X2I1D2U2C2
6	S1E2X1I2D1U1C1	8	S1E2X2I2D2U2C2
9	S2E1X1I1D1U1C1	11	S2E1X2I1D2U2C2
10	S2E1X1I2D1U1C1	12	S2E1X2I2D2U2C2
15	S2E2X1I1D1U1C1	17	S2E2X2I1D2U2C2
16	S2E2X1I2D1U1C1	18	S2E2X2I2D2U2C2

However, depending on the probability chosen, and the configuration selected for the present situation, not all possible states will be reached. This is not necessarily a problem when considering a global or regional situation, as there is only one (or at most a few) possible current states. For urban environments, the total number of current situations is far more numerous; although the future of one particular urban scenario could be mapped out, it is unlikely that the entire Faustian Tree could be generated in this way. Taking this into account, and allowing for the fact that time constraints permitted no prior consideration of the Faustian Tree by the workshop participants, the tree was constructed using the following method. We have allowed transitions between factors to occur based on the logical premise that small changes between levels of the sectors were more likely than large ones. For the data shown in Table 9, this corresponds to transitions between factors adjacent to each other because they are ordered from best-case to worst-case. Thus, for the sector Social Infrastructure, for example, we allow the transitions S1 → S2 and S2 → S3 but disallow S1 → S3.[9] While such a change could be possible (i.e. due to a massive disaster such as an earthquake or an epidemic such as SARS), omitting it makes the generation of the Faustian Tree and tracing the possible evolution of scenarios much simpler. While it is also true that the factors of certain sectors will influence the likelihood of transitions in other factors[10], we have not considered this effect in constructing the tree. Thus, we have allowed all such transitions to occur, and not made any judgement on their reversibility. Where possible, factors connected by transitions have been placed adjacent to each other (as much as practicable). In this way, all possible configurations appear in the tree. Once constructed, the structure can always be revisited and revised.

The resultant Faustian Tree is shown in Figure 1, together with a figure showing the gross evolutionary trends. The most interesting aspect is that there are no single step transitions for the sectors Societal Expectation, Urban Behaviour and Social Behaviour. This largely comes about because of the low resolution in these three sectors (only two possible factors) and because we have disallowed the co-existence of C2 with X1 (societal expectation satisfied), D1 (booming economy) and U1 (urban behaviour a shining example). This is quite reasonable, given that these factors could not conceivably co-exist with a factor of intolerant social behaviour in which there was possible violence. In order to change factors in these sectors, it is necessary for simultaneous transitions in Societal Expectation, Economic Development, and Urban Behaviour. There are eight such transitions, as listed in Table 10. This indicates that the evolution of poor social behaviour (as evidenced by

[9] In this paper, a transition in sector from factor i to factor j is abbreviated S_{ij}.

[10] For example, an improvement in environmental factors is much less likely when the social infrastructure and economic development are poor.

disorder or violence) is not likely to occur in isolation, but with a resultant worsening in other sectors. The sector Urban Behaviour is more an indicator of external perception, rather than being a tangible property of the urban environment. Transitions in this sector will be led by changes in other sectors, rather than occurring in isolation. The Faustian Tree generated here is consistent with changes in urban behaviour resulting with changes in societal expectation (and a concomitant worsening in urban behaviour).

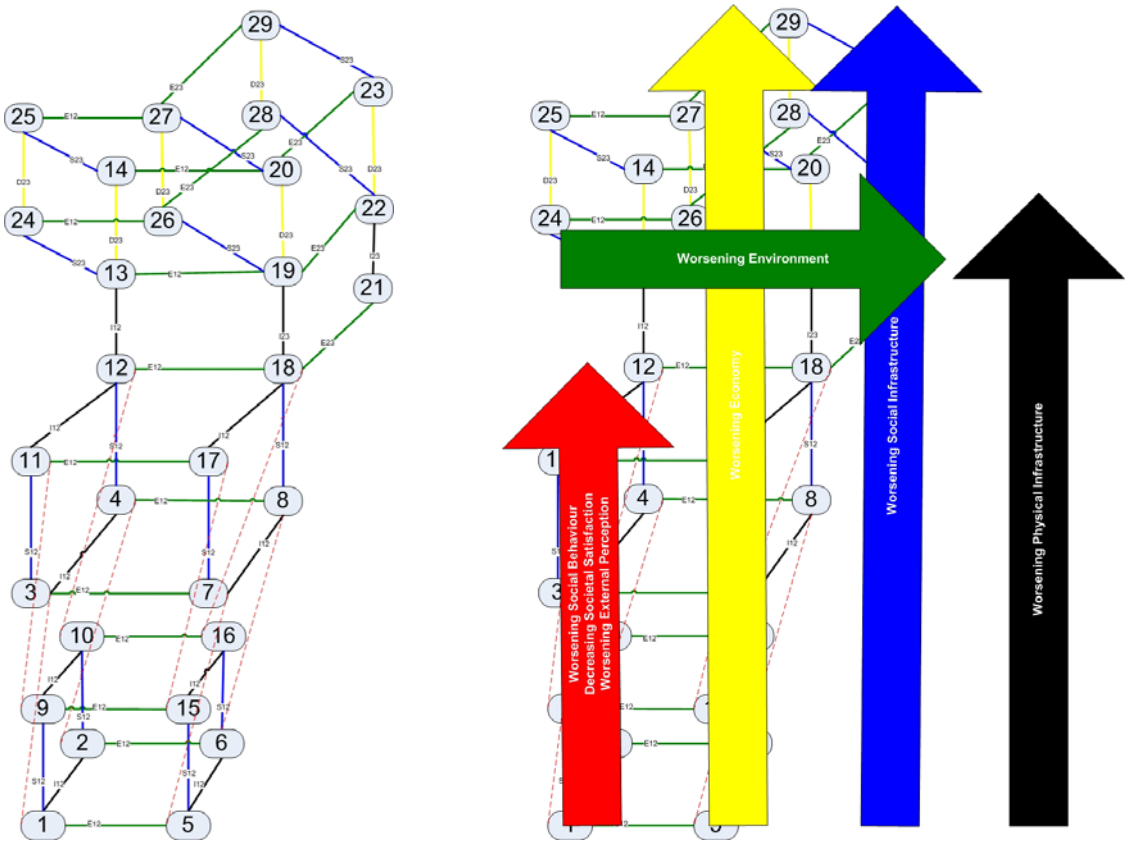

Figure 1. Left: Faustian Tree derived from configurations presented in Table 9, Right; gross trends in level of sectors to show direction of increasingly poor urban environment. The eight $X_{12}U_{12}C_{12}$ transitions are shown as dashed red lines.

While such simultaneous transitions are indicated in eight cases, the probability of them occurring is not likely to be the same in each case. It is plausible that configurations in which the factors of each sector are worse are more likely to result in undesirable transitions. That is, the transition 16 (S2E2X1I2D1U1C1) → 18 (S2E2X2I2D2U2C2) is more likely than the transition 1 (S1E1X1I1D1U1C1) → 3 (S1E1X2I1D2U2C2). The opposite is true for the reverse transitions.

4.1.2 Workshop 3

In the previous section, it was seen how simplifying the original set of sectors could be used to produce a manageable number of configurations. However this runs the risk of loss of detail and oversimplification. Even with considerable clustering of factors, it was still only possible to reduce the total number of configurations in Workshop 3 down to 95. However, as described in section 3.4.1, one way of avoiding this problem is to conduct a

'mini-FAR', in which particular sectors are fixed, and all the others are allowed to vary. In this case, we have chosen to investigate the possible futures of the Megacity, by fixing the factor of the sector Infrastructure and Environment to Megacity, and allowing the other Sectors to vary as normal (see Table 11). We also allowed the following similar factors to be clustered.

G1 + G2	Competent and Fully Functional Governance
S4 + S5	Fragmented and Ineffective Security
E3 + E4	Weak and Stagnant Economy

Table 11. Modified set of sectors and factors derived from Workshop 3.
The factors under each sector have been re-ordered so that best-case to worst case reads top to bottom

	Sectors					
Factors	**G**overnance	**So**ciety	**S**ecurity	**I**nfrastructure and Environment	**P**opulation	**E**conomy
	G1 Fully Functional	O1 Pluralistic Stable	S1 Sound	I1 Megacity	P1 Stagnant-Segregated	E1 Strong
	G2 Competent	O2 Homogeneous Stable	S2 Excessive		P2 Stagnant-Mixed	E2 Sound
	G3 Partially Functional	O3 Pluralistic Unstable	S3 Destabilising		P3 Slow Growth-Segregated	E3 Weak
	G4 Dysfunctional	O4 Homogenous Unstable	S4 Fragmented		P4 Slow Growth-Mixed	E4 Stagnant
			S5 Ineffective		P5 Dynamic-Segregated	
					P6 Dynamic-Mixed	

The pairwise comparison for this new set of data is presented in Table 12. The relaxing of these anomalous pairs resulted in 57 unique configurations, which are shown in Table 13.

As a consequence of clustering similar factors, each scenario consists of a number of configurations joined by internal transitions. This is best illustrated by an example. Consider configurations 1 and 2, and the transition between them (E1 ↔ E2). Configurations 1 (G1-2O1S1I1P3E1) and 2 (G1-2O1S1I1P3E2) are clusters each consisting of 2 internal states joined by internal transitions G1 ↔ G2, as shown in Figure 2. Configurations where two groups of states have been clustered have four internal configurations (this is the case for configurations 38-39, 46-48 and 55-57, which have the clustering S4-5 and E3-4). Thus, configurations 55 and 57 (and the transitions between them) form a cube, when all the internal states are considered.

Table 12. Pairwise comparison matrix for data presented in Table 11.
Y indicates that the factors can co-exist, N indicates that the factors are anomalous.

	O1	O2	O3	O4	S1	S2	S3	S4	S5	I1	P1	P2	P3	P4	P5	P6	E1	E2	E3	E4
G1	Y	Y	N	N	Y	N	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N
G2	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
G3	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y
G4	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y
O1					Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
O2					Y	Y	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y
O3					N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y
O4					N	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	N	N	Y	Y
S1										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
S2										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
S3										Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y
S4										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
S5										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
I1											N	N	Y	Y	Y	Y	Y	Y	Y	Y
P1																	N	Y	Y	Y
P2																	Y	Y	Y	Y
P3																	Y	Y	Y	Y
P4																	Y	Y	Y	Y
P5																	Y	Y	Y	Y
P6																	Y	Y	Y	Y

Table 13. Scenario configurations derived from the sectors and factors in Table 11

Configuration No.	**Configuration**	**Configuration No.**	**Configuration**	**Configuration No.**	**Configuration**
1	G1-2O1S1I1P3E1	20	G1-2O2S1I1P6E1	39	G3O2S4-5I1P6E3-4
2	G1-2O1S1I1P3E2	21	G1-2O2S1I1P6E2	40	G3O3S2I1P3E3-4
3	G1-2O1S1I1P4E1	22	G1-2O2S1I1P6E3	41	G3O3S2I1P4E3-4
4	G1-2O1S1I1P4E2	23	G1-2O2S4I1P4E1	42	G3O3S2I1P5E3-4
5	G1-2O1S1I1P5E1	24	G1-2O2S4I1P4E2	43	G3O3S3I1P3E3-4
6	G1-2O1S1I1P5E2	25	G1-2O2S4I1P4E3	44	G3O3S3I1P4E3-4
7	G1-2O1S1I1P6E1	26	G1-2O2S4I1P6E1	45	G3O3S3I1P5E3-4
8	G1-2O1S1I1P6E2	27	G1-2O2S4I1P6E2	46	G3O3S4-5I1P3E3-4
9	G1-2O1S4I1P3E1	28	G1-2O2S4I1P6E3	47	G3O3S4-5I1P4E3-4
10	G1-2O1S4I1P3E2	29	G2O2S1I1P4E4	48	G3O3S4-5I1P5E3-4
11	G1-2O1S4I1P4E1	30	G2O2S1I1P6E4	49	G4O3S2I1P3E3-4
12	G1-2O1S4I1P4E2	31	G2O2S4I1P4E4	50	G4O3S2I1P4E3-4
13	G1-2O1S4I1P5E1	32	G2O2S4I1P6E4	51	G4O3S2I1P5E3-4
14	G1-2O1S4I1P5E2	33	G2O3S4I1P3E3-4	52	G4O3S3I1P3E3-4
15	G1-2O1S4I1P6E1	34	G2O3S4I1P4E3-4	53	G4O3S3I1P4E3-4
16	G1-2O1S4I1P6E2	35	G2O3S4I1P5E3-4	54	G4O3S3I1P5E3-4
17	G1-2O2S1I1P4E1	36	G3O2S2I1P4E3-4	55	G4O3S4-5I1P3E3-4
18	G1-2O2S1I1P4E2	37	G3O2S2I1P6E3-4	56	G4O3S4-5I1P4E3-4
19	G1-2O2S1I1P4E3	38	G3O2S4-5I1P4E3-4	57	G4O3S4-5I1P5E3-4

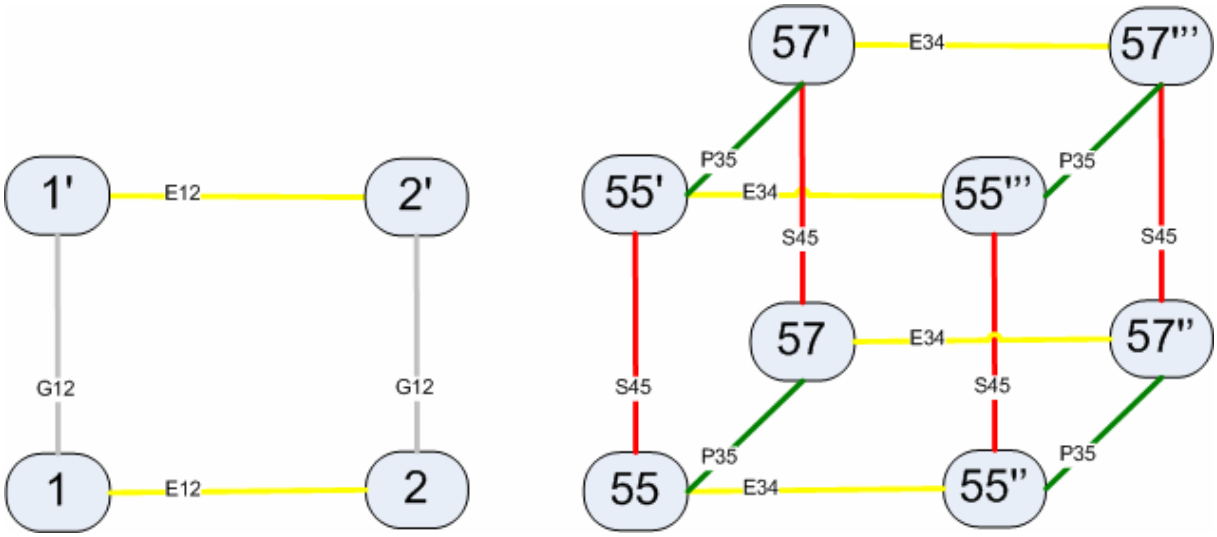

Figure 2. Illustration of internal configurations resulting from clustering similar factors.

However, in some cases, the pairwise comparison resulted in the following configurations in which the only one of the clustered states could exist:

Configurations 29-35: G2 only (G1 cannot co-exist with O3 or E4)
Configurations 9-16, 23-28 and 31-35: S4 only (S5 cannot coexist with G1-2)
Configurations 19, 22 and 28: E3 only (E4 cannot co-exist with G1)
Configurations 29-32: E4 only (E4 cannot co-exist with G1).

As a consequence, we observe no S1 ↔ S5 transitions, only S1 ↔ S4 transitions. These limitations also give rise to a limited number (4) of E3 ↔ E4 transitions.

We have constructed the tree in a similar manner to before, however, in this case, there are more transitions possible because the different factors under each sector are not always ordered (i.e. from bad to worse). For example for Security, while 'sound' is clearly the best case for this sector, the others cannot be readily ordered. Consequently, we can allow transitions between any of the factors under Security (except for S1 → S5 as discussed below). For the other sectors we allow the transitions O1 → O3, O2 → O4, P1 → P3, P2 → P4, P3 → P5 and P4 → P6, as these are single transitions (e.g. P1 → P3 is a change only in the growth from stagnant to slow, with no change in the structure (segregated or mixed)). However we disallow O2 → O3 and P4 → P5, as they are composite transitions (e.g. P4 → P5 is a change in both the settlement pattern (mixed → segregated) and also the population growth (slow → dynamic)). As we are particularly interested in changes in stability, we have still indicated the O2 ↔ O3 transitions in the Faustian Tree, even though they are a composite transition (a change in social structure (homogeneous → pluralistic) and in social behaviour (stable → unstable)).

The Faustian Tree (Figure 3), drawn in this manner, appears very busy and is difficult to follow. In order to simplify it, it is necessary to look at further clustering. We achieved this by looking at the tree for patterns in the distribution of factors for each sector. For Governance, Society, Economy, and to a lesser extent Security, there is a definite ordering in the structure, as seen in Figure 3 for Society. The different factors of Population, on the

other hand, are distributed evenly across the tree. In noting this, we constructed the tree by grouping configurations with factors linked by transitions in Population, but with unique factors of the other sectors. The resultant Faustian Tree appears in Figure 4. The clusters which result from this grouping, appear in Table 14.

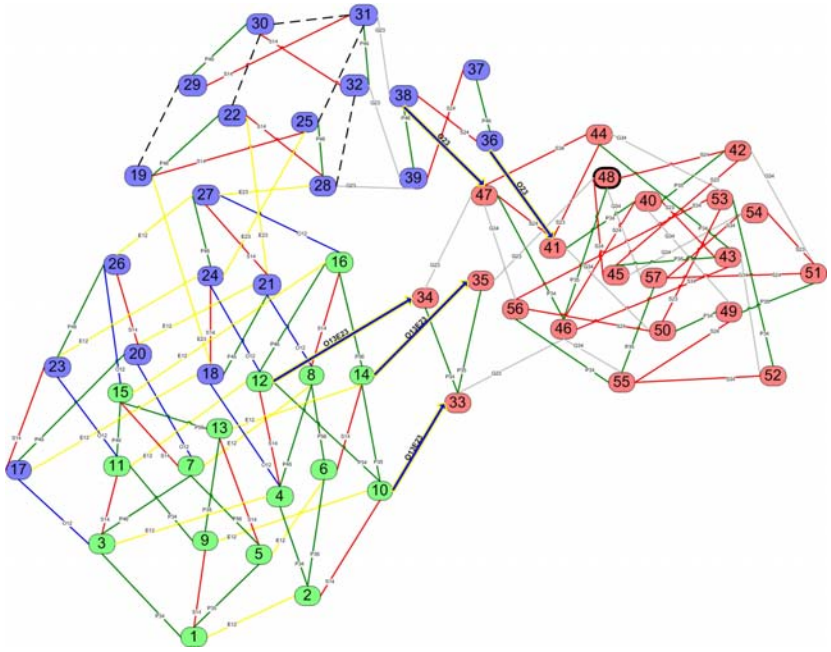

Figure 3. Illustration of the trend in factors of Society across the Faustian Tree. O1 factors are green, O2 factors are blue and O3 factors are red.

Table 14. Clusters obtained by grouping configurations based on factors of Population

Cluster	Configurations	Unique Factors	Cluster	Configurations	Unique Factors
C1	1 3 5 7	G1-2O1S1E1	C12	31 32	G2O2S4E4
C2	9 11 13 15	G1-2O1S4E1	C13	33 34 35	G2O3S4E3-4
C3	2 4 6 8	G1-2O1S1E2	C14	36 37	G3O2S2E3-4
C4	10 12 14 16	G1-2O1S4E2	C15	38 39	G3O2S4-5E3-4
C5	17 20	G1-2O2S1E1	C16	40 41 42	G3O3S2E3-4
C6	23 26	G1-2O2S4E1	C17	43 44 45	G3O3S3E3-4
C7	18 21	G1-2O2S1E2	C18	46 47 48	G3O3S4-5E3-4
C8	24 27	G1-2O2S4E2	C19	49 50 51	G4O3S2E3-4
C9	19 22	G1-2O2S1E3	C20	52 53 54	G4O3S3E3-4
C10	25 28	G1-2O2S4E3	C21	55 56 57	
C11	29 30	G2O2S1E4			

The method used to show transitions between clusters in Figure 4 is as follows. For transitions between clusters of three or four configurations (e.g. C1↔ C2, C16 ↔ C17), transition lines from the centre of each cluster to the centre of the adjacent cluster indicate that all configurations within the cluster may transition to the configuration in the corresponding position in the adjacent cluster (e.g. 1↔ 2, 49 ↔ 55 etc), except for C4 ↔ C13, when transitions occur only between configurations in the corresponding position. Where transition lines come from the side of the cluster, then only the configurations adjacent to that side may transition (e.g. 3 ↔ 17 and 7 ↔ 20). For clusters containing two configurations, transition lines from the side of the cluster indicate that both

configurations may transition to the configuration in the corresponding position in the adjacent cluster (e.g. 18 ↔ 24 and 21 ↔ 27). Where transition can only occur between single configurations, then the transition is shown originating from that configuration (e.g. 36 ↔ 41).

Note that we are not asserting that evolution can only occur through small changes in one sector at a time, this is just how we have constructed the tree. While it is likely that small changes are more probable than larger ones, simultaneous transitions in several sectors are plausible, especially as the sectors are not independent, with a change in one sector potentially being a driver for change in another sector. For example, the transition from C9 to C11 (E3 ↔ E4) can be followed by transitions to C12 (S1 ↔ S4) and to C15 (G2 ↔ G3), but it is also plausible that worsening in the economy, security and governance could occur concurrently (i.e. C9 ↔ C15), and on a similar time-scale to a single transition.

As seen for the previous Faustian Tree (Figure 1), there are no single transitions corresponding to a transition from a stable to unstable society. There are only five compound transitions; three of these correspond to a simultaneous transition O1 ↔ O3 and E2 ↔ E3, which occurs for the transition from cluster 4 to cluster 13.[11] This results from the factors O3 and E2 being unable to co-exist and is consistent with the state of the economy declining under a state of social instability. It is also unlikely that governance could remain at a level of competence in the long term; we note that cluster 13 transitions to cluster 18 via the transition G2 ↔ G3, which seems likely to occur, unless stable social behaviour is restored through a reverse transition back to cluster 13 (security is already in a fragmented state).

The other two transitions to an unstable society are the compound transitions O2 ↔ O3, which occur for 36 (G3O2S2I1P4E3-4) ↔ 41 (G3O3S2I1P4E3-4) and 38 (G3O2S4-5I1P4E3-4) ↔ 47 (G3O3S4-5I1P4E3-4). The transition from a stable, homogeneous society to an unstable, pluralistic society is plausible, given the conditions of partially functional governance, excessive or fragmented/ineffective security and weak/dysfunctional economy. It could correspond to the creation of a number of groups in conflict as a result of these poor social conditions. While improvement is possible (either through a reverse transition or an improvement in governance to cluster 13), it seems equally likely that conditions would remain the same or worsen, with governance changing to totally dysfunctional, with continuing poor economy and only variations in security. Under these conditions, it is arguable as to which state of security could be considered worse.

While the preceding discussions give some insight into the possible evolution of urban states, some weaknesses are apparent. The main one is having the sector Infrastructure and the Environment fixed at 'Megacity', while the other sectors can change. It seems somewhat likely that these characteristics would vary quite considerably depending on the factors of the other sectors, yet this does not occur. One solution to this is to revisit the pairwise comparison table. Another approach is to use generic factors for all sectors, which is adopted in the following section.

[11] 10 (G1-2O1S4I1P3E2) ↔ 33 (G2O3S4I1P3E3-4), 12 (G1-2O1S4I1P4E2) ↔ 34 (G2O3S4I1P4E3-4) and 14 (G1-2O1S4I1P5E2) ↔ 35 (G2O3S4I1P5E3-4)

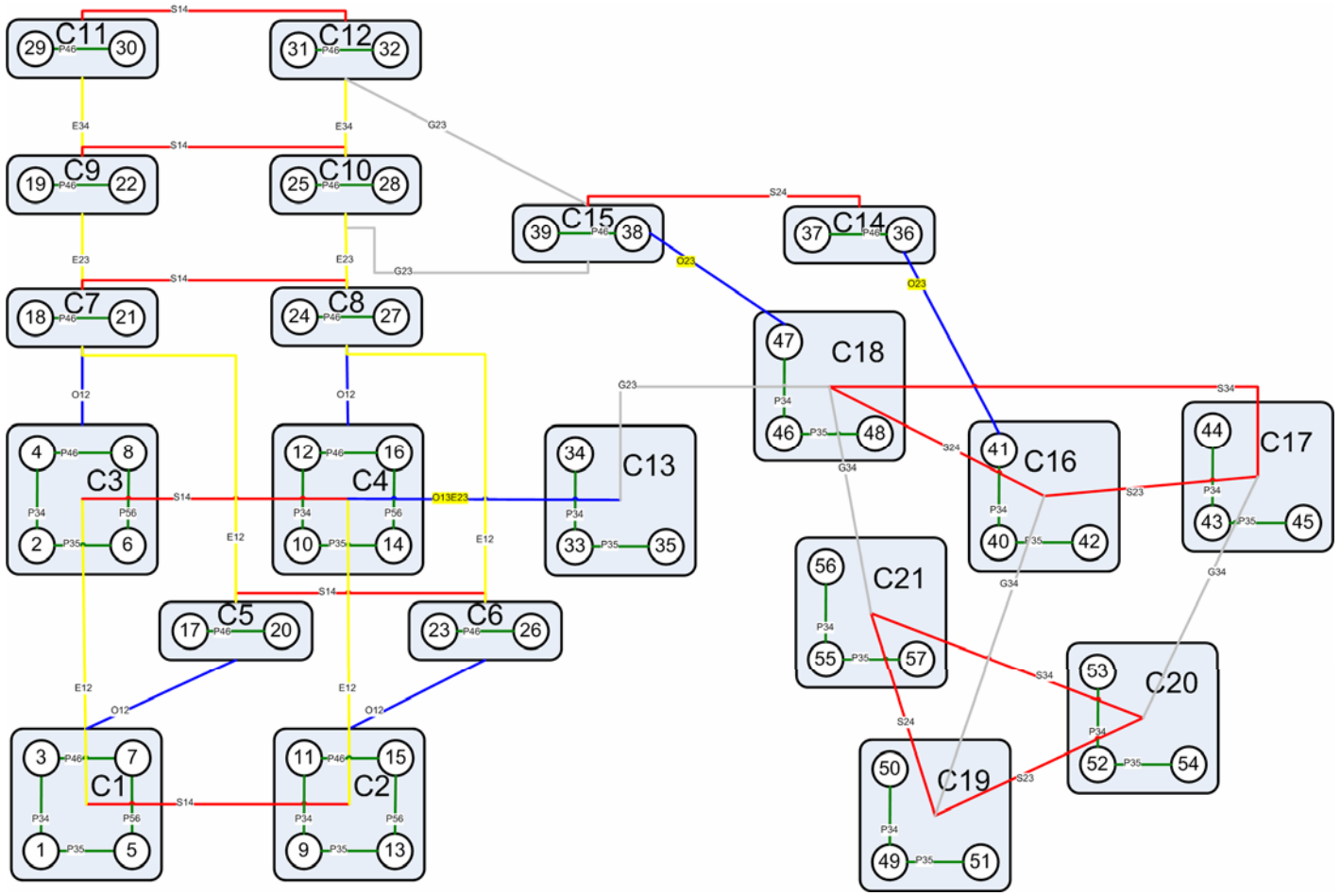

Figure 4. Faustian Tree for Workshop 3.
The best-case scenarios lie at the bottom left of the figure (C1 and C5); Economy worsens towards the top of the figure. The worst-case scenarios lie to the right of the figure, with poor security, economy and governance and an unstable population. According to the pairwise comparison from Workshop 3, Infrastructure and the Environment transition from Megacity to Modern Metropolis only from clusters C1, C3, C5, C7 and C9.

4.2 Combined Workshops

After the conclusion of the three workshops, the results of the three groups were examined in order to look for commonality. A comparison of the sectors and factors appearing in Tables 1-6 shows a number of similarities, which are examined in more detail in Table 15.[12] Inspection of Table 15 demonstrates that from the three workshops, it is possible to identify six common sectors. These are presented in Table 16 and the definitions for each sector appear in Table 17. Using the factors from the three workshops, it was possible to determine some plausible factors for these sectors; these also appear in Table 16. The sectors not apparently common to the three workshops are nevertheless to some extent subsumed within the final set of sectors. For example, the sector urban behaviour could be an overall measure of all the other sectors; an urban precinct that was a shining example would tend to be stable, totally secure, with functional governance, societal equity and well developed infrastructure and economy. An urban centre that was poorly regarded would tend to be the opposite (unstable, poor security and governance etc). The sector awareness (linked to education and exposure to ideas and outside influences) is to some extent covered by human and physical welfare, as deep awareness could be associated with fully developed human and physical welfare, and limited awareness could be associated with limited or non-existent human and physical welfare. The final sector, population, does not initially appear to have any commonality with the final set of six sectors. While this sector is important in describing an urban environment, we have seen from the previous section that the population growth can be stagnant, slow or dynamic, regardless of what the other factors are. In terms of looking for drivers for population behaviour and social change, it is more relevant whether such population growth outweighs the ability of the urban environment to deal with it. This aspect is reflected in the other sectors. For example, an urban centre unable to cope with urban growth could not be described as having fully functional governance, and would not have fully developed infrastructure. There would also be inequity, as the urban environment would not provide equally for all inhabitants. However, an urban centre with functional governance, fully developed infrastructure and a strong economy may be able to match a dynamic population growth. As discussed in section 3.4.1 these aspects can be explored further when describing scenarios derived from the existing states, or by using a mini-FAR session.

[12] Indeed, all three workshops show a level of similarity to the STEEPV model (see footnote 6) [12].

Table 15. A comparison of the sectors and their definitions from all three workshops

Workshop 1	Workshop 2	Workshop 3
Social Behaviour The diversity of factors such as ethnicity, religion, beliefs, language and values, that influence people's behaviour and the way the society functions	**Diversity** The presence of a variety of cultures and ideologies, and their interaction	**Society** The character of the social structures (ethnicity, gender, religion and class) and the corresponding behaviours and value systems that support them
Social Infrastructure The institutional framework that allows the urban society to function; includes government, security, health and education	**Governance** Modes of regulation and control for shaping the behaviour of community	**Governance** The political, administrative and legal systems used to organise, control, direct and manage the city
Physical Infrastructure The tangible aspects of an urban environment within which the human interacts, which include: development and enforcement of laws, regulations and rules, physical components of urban development, and natural geographic factors that influence development	**Welfare** The identification and targeting of help to disadvantaged individuals or groups through provision of organised programs	**Infrastructure and Environment** The quality of the overall infrastructure and the characteristics of the supporting environment
Environmental Factors The environmental factors, such as natural resources, pollution and climate that influence the running of the physical infrastructure affecting the health of the urban population and their standards of living		
Economic Development The wealth and its distribution within the urban environment	**Prosperity** The wealth and quality of infrastructure of a community	**Economy** The production and distribution of wealth (including goods and services) in society and its influence on the functioning of other societal institutions
		Population The size, structure, composition, growth and dynamics of a population and its settlement pattern
Urban Behaviour The performance of the urban environment as influenced by or judged from an external point of view		
	Security The community's perception of threat to their personal safety	**Security** Safeguarding society from any threats to the individual and collective well-being
Societal Expectation People's perceptions of what they want, in the context of what the urban environment provides	**Equity** A sense of fairness relative to the wider community	
	Awareness Level of understanding of the world beyond the community	

Table 16. Final set of urban sectors and factors

	Sectors					
	Social **B**ehaviour	**U**rban Security	**G**overnance	**S**ocietal Equity	**H**uman and Physical Welfare	**E**conomic Prosperity
Factors	B1 Tolerant Co-existence (peaceful)	U1 Totally Secure (safe for all)	G1 Functional	S1 Equity	H1 Fully Developed	E1 Affluent (strong and booming)
	B2 Intolerant co-existence (may lead to clashes between groups	U2 Selective (unstable and fragmented)	G2 Partially Functional	S2 Inequity	H2 Developing	E2 Weak (emerging/ slow growing)
	B3 Societal Breakdown (clashes between groups)	U3 Urban Jungle (everyone for himself, life threatening)	G3 Dysfunctional	S3 Discrimination	H3 Non-existent	E3 Subsistence (stagnant and dysfunctional)

Table 17. Definition of final set of urban sectors

Sector	**Definition**
Social Behaviour	The character of the social structures (ethnicity, gender, religion and class) and the corresponding behaviours and value systems that support them.
Urban Security	The performance of the urban environment in safeguarding the urban society from any threats to the individual and collective well-being.
Governance	The political, administrative and legal frameworks that allow the urban society to organise, control, direct and manage their environment.
Societal Equity	People's perceptions of what is fair relative to the wider community and what they can expect in the context of what the urban environment provides.
Human and Physical Welfare	The quality and influences of the overall infrastructure and the characteristics of the supporting environment on the physical and mental well being of the individual and the collective society.
Economic Prosperity	The production and distribution of wealth (including goods and services) in society and its influence on the functioning of other societal institutions.

4.2.1 Pairwise Comparison and Clustering

The pairwise comparison for the sectors and factors from the combined workshop results is shown in Table 18. While subjective, it follows reasonably intuitively from the definition of the sectors and the underlying factors. For example, a state of tolerant co-existence is highly unlikely where the security corresponds to an urban jungle. Similarly, by definition, partially functional or dysfunctional governance cannot bring about fully developed human and physical welfare; these factors can therefore not co-exist. If at a later stage, examples are found that contradict the chosen anomalies, it is a simple matter to revisit the data and recalculate the new configurations.

Table 18. Pairwise comparison for relaxation of anomalous factors

	U1	U2	U3	G1	G2	G3	S1	S2	S3	H1	H2	H3	E1	E2	E3
B1	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y
B2	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y
B3	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y
U1				Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N
U2				Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
U3				N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y
G1							Y	Y	N	Y	Y	N	Y	Y	N
G2							Y	Y	Y	N	Y	Y	Y	Y	Y
G3							N	Y	Y	N	Y	Y	N	Y	Y
S1										Y	Y	N	Y	Y	N
S2										N	Y	Y	Y	Y	Y
S3										N	Y	Y	N	Y	Y
H1													Y	Y	N
H2													Y	Y	N
H3													N	Y	Y

Table 19. Configurations

Configuration No.	Configuration	Configuration No.	Configuration
1	B1U1G1S1H1E1	21	B2-3U2G2S3H3E2
2	B1U1G1S1H1E2	22	B2-3U2G2S3H3E3
3	B1U1G1S1H2E1	23	B2-3U2G3S2H2E2
4	B1U1G1S1H2E2	24	B2-3U2G3S2H3E2
5	B1U1G1S2H2E1	25	B2-3U2G3S2H3E3
6	B1U1G1S2H2E2	26	B2-3U2G3S3H2E2
7	B1U1G2S1H2E1	27	B2-3U2G3S3H3E2
8	B1U1G2S1H2E2	28	B2-3U2G3S3H3E3
9	B1U1G2S2H2E1	29	B2-3U3G2S2H2E2
10	B1U1G2S2H2E2	30	B2-3U3G2S2H3E2
11	B1U2G1S2H2E1	31	B2-3U3G2S2H3E3
12	B1U2G1S2H2E2	32	B2-3U3G2S3H2E2
13	B1U2G2S2H2E1	33	B2-3U3G2S3H3E2
14	B1U2G2S2H2E2	34	B2-3U3G2S3H3E3
15	B1U2G3S2H2E2	35	B2-3U3G3S2H2E2
16	B2U2G2S2H2E1	36	B2-3U3G3S2H3E2
17	B2-3U2G2S2H2E2	37	B2-3U3G3S2H3E3
18	B2-3U2G2S2H3E2	38	B2-3U3G3S3H2E2
19	B2-3U2G2S2H3E3	39	B2-3U3G3S3H3E2
20	B2-3U2G2S3H2E2	40	B2-3U3G3S3H3E3

The relaxation of anomalous factors reduces the number of configurations from a maximum possible 729 configurations to a more manageable 64. The next phase was to cluster very similar scenarios by seeing whether certain factors could be combined. Inspection of Table 18 shows that B2 and B3 (intolerant co-existence and societal breakdown) have the same pairwise comparison with all the other factors (except for E1) and could therefore be clustered. This seems reasonable, as the former could quite

conceivably lead to the latter.[13] This final clustering gave rise to 40 scenario clusters, the configurations for which appear in Table 19.

4.2.2 Faustian Tree

A Faustian Tree, showing the derived scenarios and the possible transitions (evolutionary paths) between them appears in Figure 5. The method for constructing this tree is the same as previously, with every configuration included, but allowing only transitions in one sector at a time, and allowing only a single step in the factor-change. As previously, no attempt is made to indicate the relative probabilities of a transition, or whether or not a transition is reversible. While easier to follow than the unrefined tree derived in section 4.1.2, it can be significantly improved with further clustering, as described in the following sections.

The tree breaks down nicely into two distinct areas, based on whether social behaviour is in a state of tolerant co-existence or intolerant co-existence/societal breakdown. The two groups are connected by only three transitions. The B1 group of configurations contains 14 different scenarios, whereas the B2 group contains 24, and is much more complicated in structure. This is similar to the behaviour of the previous two Faustian Trees, where there were only a small number of transitions from stable to unstable social behaviour, when compared with transitions in other sectors. Transitions from B1 → B2 occur from configurations 13 (B1U2G2S2H2E1), 14 (B1U2G2S2H2E2) and 15 (B1U2G3S2H2E2). In these cases, any of the other sectors could be considered drivers for this change, especially governance for 15 (G3) (but not economic prosperity for 13 (E1)). This observation could simply be consistent with situations with intolerant or violent social behaviour not readily fixing themselves.

4.2.3 Basic Clustering

Some basic elements of the Faustian Tree are demonstrated in Figure 6. These diagrams show the division of configurations for the scenarios based on the unique factors of the other sectors. For the factors derived in this study, factor 1 of each sector could be considered the best situation (e.g. fully functional governance), whereas factor 3 could be considered the worst (e.g. dysfunctional governance). Thus, the worst factors for each of the six sectors appear in red, the best factors appear in blue. The worst urban environments would therefore appear where the red areas overlapped.

[13] Given that we are looking for conditions leading to societal breakdown, the observed relationship between B2 and B3 is particularly useful. All B2 scenarios can evolve directly into B3 scenarios, except for scenario 16 (with E1). Similarly, the same transitions can occur between all B3 states that occur for B2 states.

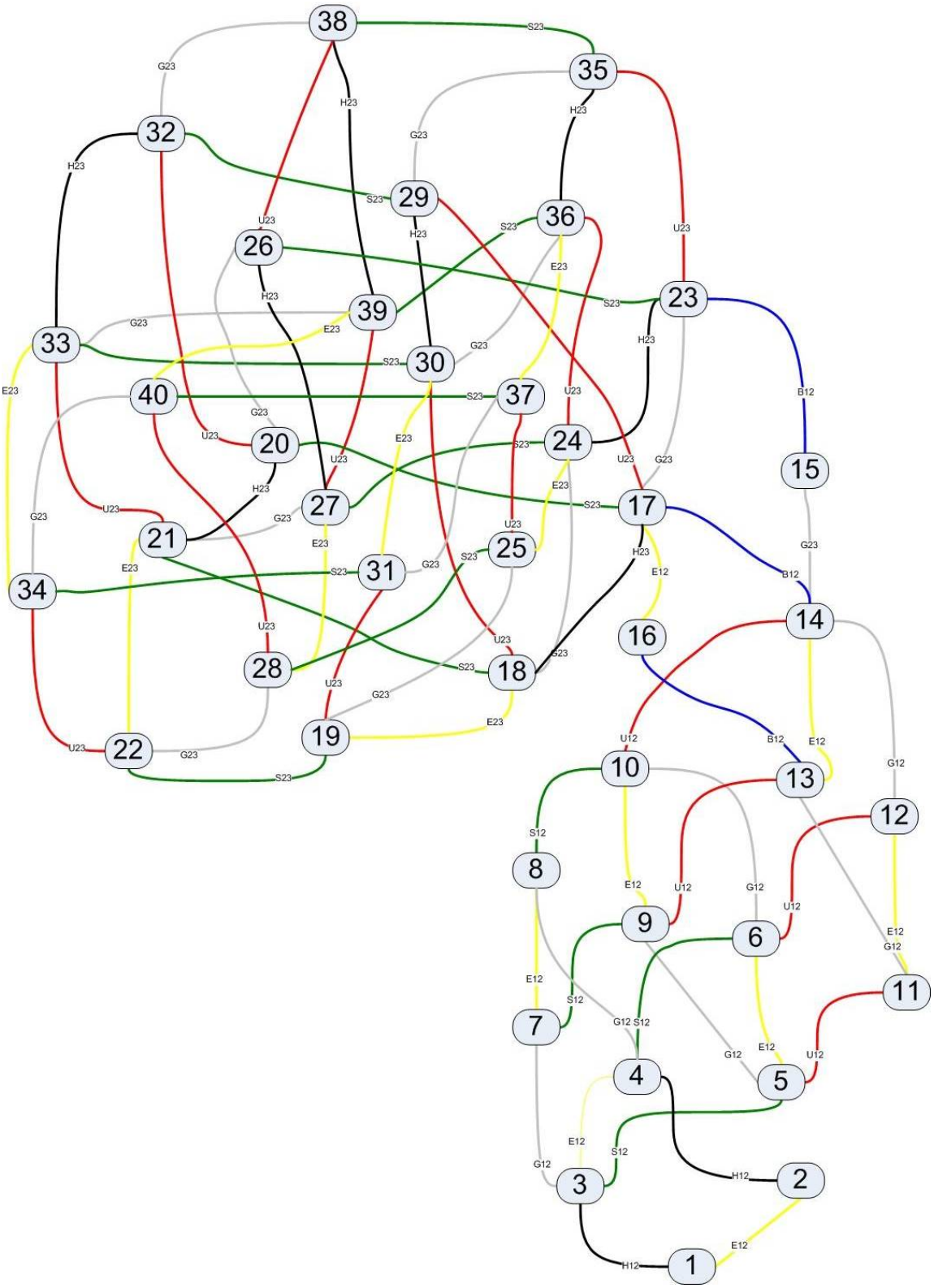

Figure 5: Faustian Tree for configurations derived from the final set of sectors and factors shown in Table 16

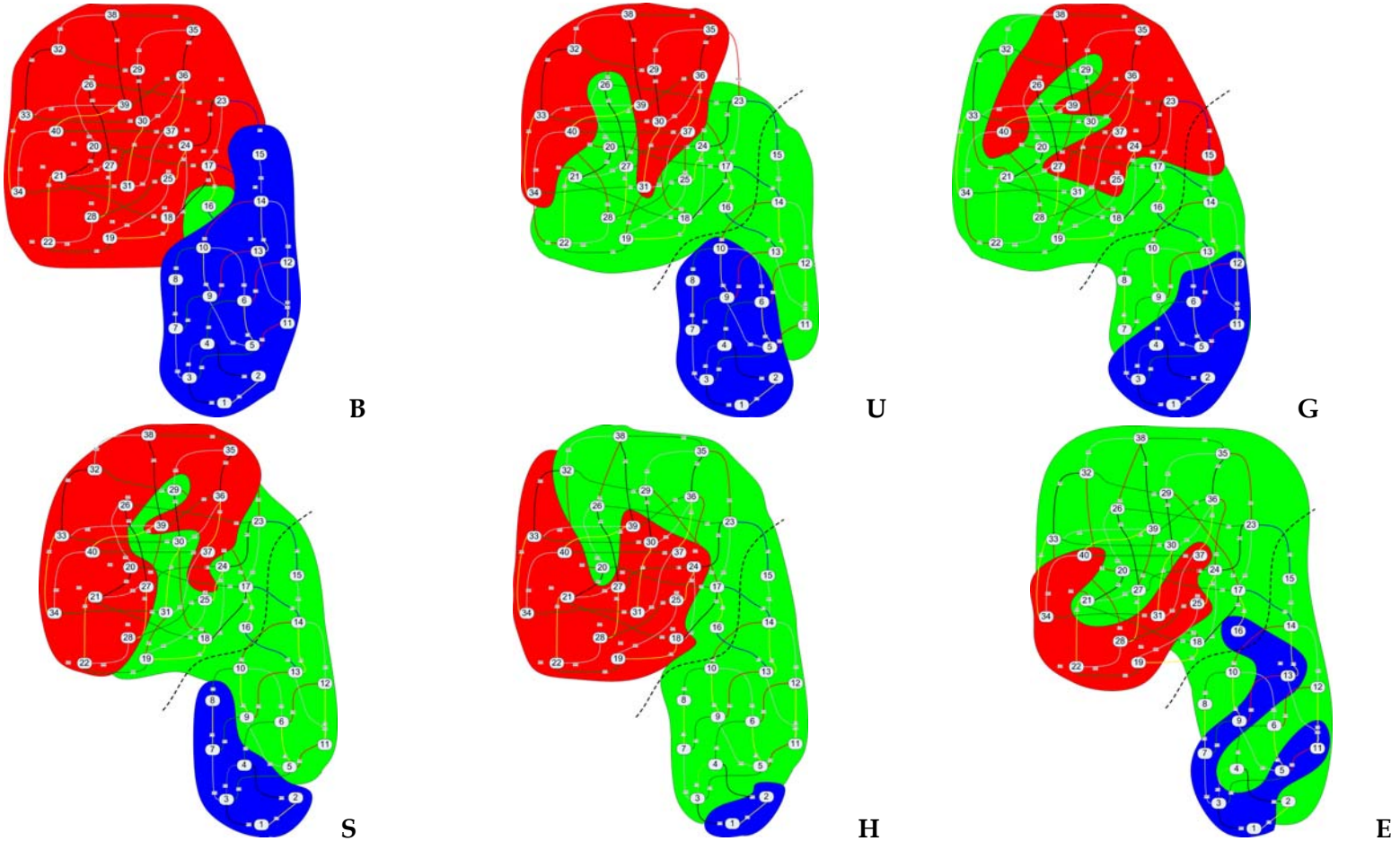

Figure 6. Division of scenarios based on factors of each of the six sectors.
Top left: B1/B2/B3 configurations; top centre: U1/U2/U3 configurations; top right: G1/G2/G3 configurations; bottom left: S1/S2/S3 configurations; bottom centre: H1/H2/H3 configurations; bottom right: E1/E2/E3 configurations. The dashed line indicates the boundaries between B1 and B2 configurations. Factor 1 configurations (e.g. U1, G1 etc.) are shown in blue, factor 2 configurations (U2, G2 etc.) are shown in green and factor 3 configurations (U3, G3 etc) are shown in red.

4.2.4 Further Clustering

The Faustian tree shown in Figure 5 is too complex to be of use, as the number of configurations and transitions is too numerous. Further clustering may be carried out by grouping configurations in which fewer sectors have unique factors. The simplest example of this is to cluster configurations by allowing only one of the six sectors to have unique factors. This is demonstrated in Figure 6, where configurations were clustered based on the factors of only one sector, regardless of the other factors. In this case, there are only 3 groups of configurations, as each sector has only three factors. In general, if m of the 6 sectors are allowed to have unique factors, then there are $\frac{6!}{m!(6-m)!}$ possible groups of configurations.

Examination of Figure 6 shows that, apart from E1 configurations, the factors of each sector all show a reasonably systematic distribution, which means that it is not immediately apparent what approach to clustering should be adopted. However, as we are focussed on social stability in urban environments, the next step taken was to examine the six sectors, and select those which are either indicative of, or drivers for instability. In order to facilitate this process, seven of the original workshop participants were asked to rate each of the six sectors as high (H), medium (M) or low (L), in terms of their influence on urban stability. A score of 1, 2 or 3 was given to the ratings L, M and H, respectively. While these scores do not enable a great deal of differentiation, given the subjective nature of this approach, it was considered appropriate not to give too much bias towards L or H scores. The results appear in Table 20.[14]

Table 20. Scores (c_s) indicating relative contribution of each sector to urban stability

Sector	Low	Medium	High	Average	Standard Deviation
Social **B**ehaviour	3	0	4	2.1	1.1
Urban Security	0	0	7	3.0	0.0
Governance	1	3	3	2.3	0.8
Societal Equity	1	4	2	2.1	0.7
Human and Physical Welfare	1	5	1	2.0	0.6
Economic Prosperity	0	6	1	2.1	0.4

Based on these ratings, the four most important sectors could be considered to be Social Behaviour, Urban Security, Societal Equity and Governance, although only Urban Security stands out.[15] While the level of Economic Prosperity and Human and Physical Welfare may be drivers of social instability (poor economy and lack of human and physical welfare are often associated with conditions of instability), it perhaps the case that inequalities in economic

[14] An alternative method would be to utilise the analytical hierarchy process. However, this may have forced an ordering of least to most important, when the contribution of each of these sectors to urban stability may not actually be all that different.

[15] This is not especially surprising, as the focus of the workshop was to look for sectors that were drivers for human behaviour and thus ultimately stability.

prosperity across an urban population are more likely to be a driver for unrest rather than the absolute state of the economy. Similarly, the state of human and physical welfare is less likely to be a driver, than whether people feel content with what services are provided. That is, the sector Equity is probably sufficient to cover the other two. It is to be stressed that this analysis is subjective and is only one way in which to cluster the derived forty configurations. It is carried out only to simplify the Faustian Tree and subsequent analysis. The data presented here can readily be recalculated using groupings different from those that are applied here.

This new clustering gives rise to fifteen unique configurations, which are summarised in Table 21.There is only one case in which a sector with factor 3 is clustered with the same sector having factor 1; namely Cluster 7 (B2U2G2S2H2-3E1-3). In every other case, the clustering was E12 or E23 and H12 or H23. Consequently, it was decided to keep configuration 16 (B2U2G2S2H2E1) separate from Cluster 7. The resultant Faustian Tree appears in Figure 7.

The scores given in Table 20 can also be used to derive a rating (R) for each cluster based on the level of urban instability using the following empirical formula:

Equation 1 $$R = \sum_{s=1}^{6} i_s \, c_s$$

where i_s is the cluster average number of the factor for sector s (e.g. 1, 2 or 3 for G1, G2 or G3 etc.) and c_s is the score for that sector taken from Table 20, where the sum is across all six sectors. The results for this treatment appear in Table 21. They were then scaled to give a value between 1 and 10,[16] and the clusters in Figure 7 have been colour coded according to this scale, with the least stable situation in red and the most stable in blue. The result is similar to that which would have been obtained by omitting the c_s term in Equation 1; because the factors under each sector are ordered, and there is little difference between the different c_s terms. This would give an indication of the ordering of the scenarios from most desirable (all the best cases for each sector) to least desirable (all the worst cases for each sector). The strategic aim then would be to effect changes that moved the urban environment away from the least-desirable areas towards the more desirable ones. Alternatively, action could be taken to prevent changes that lead towards less-desirable scenarios. Any functioning level of governance would have urban development as part of a strategic plan; however many of the scenarios developed here do not have functioning governance, in conjunction with poor factors in the other sectors, so that such improvements are by no means assured. The potential for changes in urban scenario are explored in more detail in a later section.

[16] The unscaled scores ranged between 15.8 and 37.9, so there was no artificial differentiation between cluster scores based on this scaling.

Table 21. Clusters derived from the 40 urban configurations in Table 19 and their description

Cluster and stability score	Configuration	Description
Cluster 1 (1-4) 1.00	B1U1G1S1H1-2E1-2	A state of Tolerant Coexistence, Totally Secure, Democratically Functional Governance and Societal Equity, with Fully Developed or Developing Human and Physical Welfare and Affluent or Weak Economic Prosperity.
Cluster 2 (5-6) 2.27	B1U1G1S2H2E1-2	A state of Tolerant Coexistence, Totally Secure, Democratically Functional Governance and Societal Inequity, with Developing Human and Physical Welfare and Affluent or Weak Economic Prosperity.
Cluster 3 (7-8) 2.33	B1U1G2S1H2E1-2	A state of Tolerant Coexistence, Totally Secure, Partially Functional Governance and Societal Equity, with Developing Human and Physical Welfare and Affluent or Weak Economic Prosperity.
Cluster 4 (9-10) 2.80	B1U1G2S2H2E1-2	A state of Tolerant Coexistence, Totally Secure, Partially Functional Governance and Societal Inequity, with Developing Human and Physical Welfare and Affluent or Weak Economic Prosperity.
Cluster 5 (11-12) 3.49	B1U2G1S2H2E1-2	A state of Tolerant Coexistence, Selective Security, Democratically Functional Governance and Societal Inequity, with Developing Human and Physical Welfare and Affluent or Weak Economic Prosperity.
Cluster 6 (13-14) 4.42	B1U2G2S2H2E1-2	A state of Tolerant Coexistence, Selective Security, Partially Functional Governance and Societal Inequity, with Developing Human and Physical Welfare and Affluent or Weak Economic Prosperity.
15 5.78	B1U2G3S2H2E2	A state of Tolerant Coexistence, Selective Security, Dysfunctional Governance and Societal Inequity, with Developing Human and Physical Welfare and Weak Economic Prosperity.
16 4.85	B2U2G2S2H2E1	A state of Intolerant Co-existence, Selective Security, Partially Functional Governance and Societal Inequity, with Developing Human and Physical Welfare and Affluent Economic Prosperity.
Cluster 7 (17-19) 6.99	B2U2G2S2H2-3E2-3	A state of Intolerant Co-existence, Selective Security, Partially Functional Governance and Societal Inequity, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 8 (20-22) 7.86	B2U2G2S3H2-3E2-3	A state of Intolerant Co-existence, Selective Security, Partially Functional Governance and Societal Discrimination, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 9 (23-25) 7.91	B2U2G3S2H2-3E2-3	A state of Intolerant Co-existence, Selective Security, Dysfunctional Governance and Societal Inequity, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 10 (26-28) 8.78	B2U2G3S3H2-3E2-3	A state of Intolerant Co-existence, Selective Security, Dysfunctional Governance and Societal Discrimination, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 11 (29-31) 8.20	B2U3G2S2H2-3E2-3	A state of Intolerant Co-existence, an Urban Jungle, Partially Functional Governance and Societal Inequity, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 12 (32-34) 9.07	B2U3G2S3H2-3E2-3	A state of Intolerant Co-existence, an Urban Jungle, Partially Functional Governance and Societal Discrimination, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 13 (35-37) 9.13	B2U3G3S2H2-3E2-3	A state of Intolerant Co-existence, an Urban Jungle, Dysfunctional Governance and Societal Inequity, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.
Cluster 14 (38-40) 10.00	B2U3G3S3H2-3E2-3	A state of Intolerant Co-existence, an Urban Jungle, Dysfunctional Governance and Societal Discrimination, with Developing or non-existent Human and Physical Welfare and Weak or Subsistence Economic Prosperity.

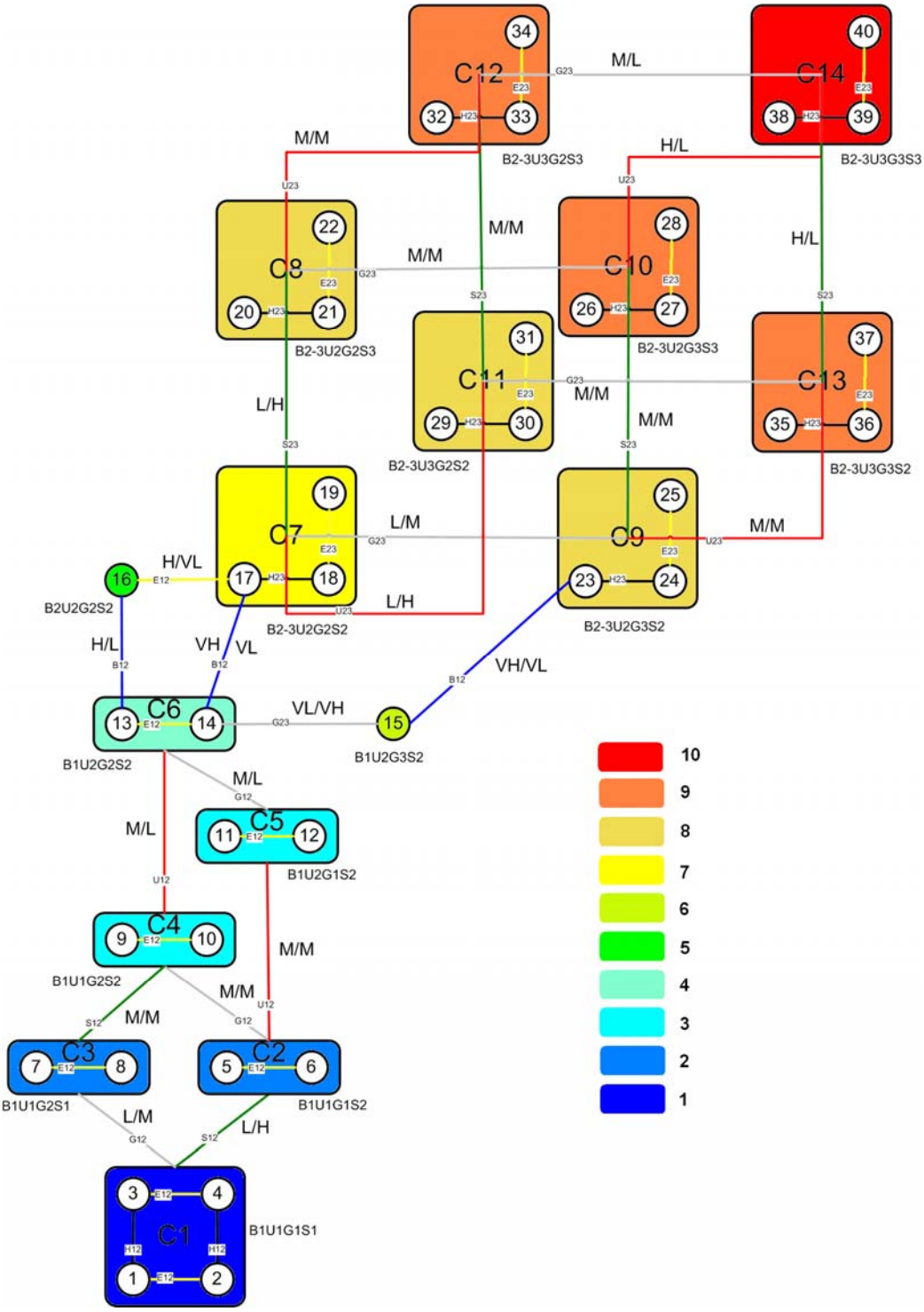

Figure 7. Faustian Tree generated using the clustering described in section 4.2.4. Indicative probabilities of transitions are shown as X/Y where X represents the forward transition S_{ij} and Y the reverse transition S_{ji}. The clusters are colour coded according to the urban stability rating shown in Table 21.

4.2.5 Scenario Generation

While it is not the aim of this study to carry out a validation using real-world urban environments, some discussion of the correlation between the scenarios derived here and known cities is appropriate to give a feel for the nature of the urban environments shown in Table 19 and Table 21. A short follow-up session with some of the DSTO staff who participated in the original workshops looked at matching known cities to the generated configurations. At one extreme, most western cities, and places such as Singapore would be consistent with cluster 1 (B1U1G1S1H1-2E1-2), i.e. social behaviour in a state of tolerant co-existence, totally secure, with fully functional governance, societal equity, fully developed or developing human and physical welfare and a strong or weak economy.[17] Specifically matching other cities was more difficult, due to a lack of detailed knowledge and the subjective nature of such a process. Previous studies under this task have also demonstrated that there is a lack of urban specific data that could be used as an effective metric for these sectors.[18] [2] Based on the discussions in the three workshops, a typical city in the AS region (e.g. SE Asia or SW Pacific) could correspond to configurations in cluster 7 (B2U2G2S2H2-3E2-3); that is, a state of intolerant co-existence, selective security, partially functional governance, societal inequity, developing/non-existent human and physical welfare and weak/ subsistence economic prosperity. Some cities in the region would be somewhat better, some would be worse. Examples of poor governance abound; e.g. the rampant corruption linked with the regime of former Philippines President Ferdinand Marcos [13]. Lack of good governance has also been identified as a recurring problem in the Solomon Islands [14]. Similarly, one of many possible examples of lack of societal equity could be the discrimination against ethnic Chinese reported to occur in many parts of SE Asia (ranging from racially based University quotas in Malaysia [15], to anti-Chinese protests and violence in Indonesia [16]). The worst-case urban environments (e.g. cluster 14: B2-3U3G3S3H2-3E2-3) would correspond to situations where everything had fallen apart; an example would be Port-au-Prince, the capital of Haiti. Haiti has been plagued by political violence for most of its history and is the poorest country in the Western Hemisphere [17]. The city has been described as a place of deep insecurity and escalating violence, where a large proportion of the population lives in extreme environmental squalor [18] and armed groups (some of which are said to be funded by political organisations) regularly carry out rape, robbery and arson [19].

With a little imagination, the cluster descriptions given in Table 21 , and the sector definitions in Table 17; the urban configurations generated here can be used to generate a plausible set of stories that describe the urban situation and can form the basis of some realistic urban scenarios, in which the ADF might operate. They do not provide the complete scenario, however, as they do not specify the threat (if it exists) and the nature and role of the ADF operation, but they provide a context for this factor. For example, for urban environments

[17] There is probably no urban society in existence which has complete security (no crime), totally functional governance (i.e. no self interest and total transparency in addition to functioning effectively), total equity and universal human and physical welfare and evenly distributed wealth for all; but these cases are about as good as it currently gets.

[18] It is important to remember that viewpoints are easily biased by considering the national picture alone, and that while the national situation can strongly influence the urban environment it does not necessarily define it.

where Security is in the state urban jungle (everyone for himself, life threatening), and a state of societal breakdown exists (clashes between groups), the mission is much more likely to be combat-centric (at least initially), with roles such as restoration of law and order (which may involve the quelling of violent groups, or the defeat of a rebel military faction) and possibly the restoration of an effective governance. In the wost cases, a number of changes would be required to return the urban environment to an acceptable state. For other configurations, the mission is less clear; it may be peace keeping (i.e. prevent U2 $\rightarrow$ U3 and B2 $\rightarrow$ B3), restoration of human and physical welfare (H3 $\rightarrow$ H2; e.g. humanitarian relief for the Boxing Day Tsunami) or protection of a particular group suffering discrimination (prevent S2 $\rightarrow$ S3). Again, it should be stressed that these scenarios provide a context, however the use of generic sectors, and the level of resolution used is not sufficient to uniquely define the likely ADF operation.

4.2.6 Transition Probabilities

Previous studies have looked at validating the Faustian Tree by use of a historical analysis. The Faustian Tree generated from the PREDICT model was found (with minor modifications) to provide a good representation of world events from 1926 - 2002 [20]. However, this model looks at drivers for global change, and is thus more amenable to this type of analysis, as we are considering the whole region. It would be anticipated that more of the configurations of a global model could be mapped to historical events, than is the case for a single urban environment.[19] An assessment of the history of several cities would be necessary for a rigorous analysis of the Urban Faustian Tree generated here, and while a possible area for future work, is beyond the scope of this study.

Over a 15-20 year time period, it is entirely plausible that transitions between factors could occur for one or more of the sectors derived in this study. While it is impossible to assign any absolute probabilities it is possible to consider the relative likelihood of transitions based on the probable influence of each of the sectors on the others. For example, improvement in human and physical welfare is more likely when the governance is fully functional (G1) and the economic prosperity is affluent (E1). Similarly, the economic prosperity may be more likely to worsen if the governance is poor. In order to facilitate this process, seven of the original workshop participants were later asked to rate each of the six sectors as high, medium or low, in terms of their influence on the other sectors. The results appear in Table 20. As before, we assigned a score of 1, 2 or 3 for ratings L, M or H, respectively. Governance appeared to have the greatest overall influence, with the other sectors having a roughly equal overall influence.

[19] In the PREDICT model, 16 of the 48 configurations mapped onto historical events in the 1926 – 2002 time period, with some configurations frequently being revisited.

Table 22. The influence of each sector on the other sectors e_{sS}

	B	**U**	**G**	**S**	**H**	**E**	**Total**
Social **B**ehaviour	-	2.7 (0.5)	2.0 (0.8)	2.4 (0.8)	1.9 (0.7)	1.7 (0.5)	10.7
Urban Security	2.3 (1.0)	-	2.4 (0.8)	2.0 (0.8)	2.1 (0.7)	2.0 (0.6)	10.9
Governance	2.1 (0.7)	2.6 (0.5)	-	2.6 (0.8)	2.7 (0.5)	3.0 (0)	13.0
Societal Equity	2.9 (0.4)	1.9 (1.1)	1.6 (0.8)	-	1.9 (0.7)	1.3 (0.5)	9.4
Human and Physical Welfare	2.1 (0.7)	1.6 (0.5)	1.7 (0.8)	2.1 (0.4)	-	1.9 (0.7)	9.4
Economic Prosperity	2.0 (0)	2.1 (0.7)	2.4 (0.8)	2.0 (0.6)	2.6 (0.5)	-	11.1

From these results, we can consider the relative likelihood (P) of a transition in a sector S_{jk} according to the following empirical formula;

Equation 2 $$P \propto \sum_{s \neq S} \left| (i_s - l) \right| e_{sS}$$

Where:

i_s is the cluster average number of the factor for sector s
l=j (k) for forward (reverse) transitions
e_{sS} is the effect of sector s on the transitioning sector S as shown in Table 22.

The term i_s-j appears because we postulate that a sector in the same factor number j as the transition S_{jk} has no significant influence. For example, if the factor of Social Behaviour is B1, but the factor of Governance is G2, and we are considering a transition B_{12}, then the latter sector can significantly affect the likelihood of transition, but the former cannot (and the opposite is true for the reverse transition B_{21}). If the factor of Governance was G3, then this should have an even greater effect. It should be stressed that this aspect of analysing the Faustian Tree would best be conducted by further brainstorming by the workshop participants, but could not be achieved due to time constraints. However, the method we have adopted still allowed some input from the workshop participants. While this uses a quantitative method to analyse a problem that is essentially very qualitative and subjective, the use of Equation 2 is likely to give more internally consistent results than if the 160 transitions are considered separately (a massive task). It allows us some indication of the relative likelihood of traversing the different pathways of the Faustian Tree and also indicates the likely changes that might occur once a particular transition took place.

The numbers generated by this treatment were normalised to give a value between 0 and 1 and then assigned labels: very low (VL; $0 \leq VL < 0.2$), low (L; $0.2 \leq L < 0.4$), medium (M; $0.4 \leq M < 0.6$), high (H; $0.6 \leq H < 0.8$) and very high (VH; $0.8 \leq VH < 1.0$). The labels appear alongside the transitions in Figure 7. The results for all transitions appear in Table 23 (Appendix C). These should in no way be considered to be the probability that a transition will occur, but is only intended to give some indication of which pathways along the Faustian tree may be more likely than others. A transition between factors/clusters over a twenty or so

year time frame is plausible; these additional labels are merely indicative of any additional push for a change to occur, based on the factors within that configuration/cluster.

In Figure 8 we show the gross evolutionary trends in the Faustian Tree, based on this treatment, where arrows indicate the direction of an M or H rating. We see that there is a strong likelihood of configurations in clusters C1, C7 and C14 remaining where they are.[20] Cluster C6 and configuration 16 are intermediates between the group of Clusters C2 - C5 (which can cycle among each other or transition either to C1 or C6) and C7. The group of clusters C8 – C13 can cycle within the group or transition to C7 or C14. Configuration 15 is particularly interesting, as there is a strong tendency to migrate to C6 (governance improves) or the group C8-C13 (social behaviour worsens). That is, without external influences, the best case, worst case and intermediate case cities tend to change less, while other categories have a tendency to migrate towards them. Further work would be required to examine this trend. However, we have certainly seen that cities currently in C1 (e.g. London, Paris, New York, Sydney) have in most cases been stable for many years; while they may have changed in absolute terms, relative to other cities at the same time they still justified belonging to C1. There are some examples where cities have moved out of C1, but only through war, rather than any swift degradation.[21] For example, prior to the Lebanese civil war (1975 -1991), Beirut was considered one of the world's most liveable cities and while it has recovered somewhat, has certainly not returned to its former standing. [21] There were also significant external influences in this case (from Israel and Syria). Grozny and Sarajevo have also suffered similarly. It seems likely that only the outbreak of war can cause rapid and significant movement along the Faustian Tree, whereas continuing poor performance in one or more of the sectors would be more likely to lead to a gradual deterioration in condition (i.e. a slow move towards the red region of the Tree). Further work is required to fully investigate these issues.

[20] Within clusters C1, C7 and C14, there is a tendency to migrate towards configurations 1, 17 and 40, respectively.

[21] Again , we are considering at most a 30-year timescale, although many cities have been stable much longer.

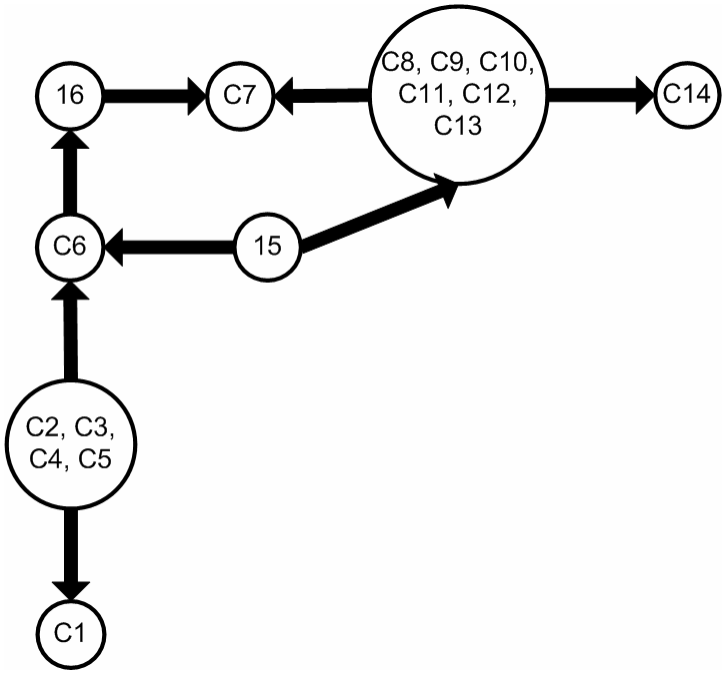

Figure 8. Overall trends in the evolution of urban configurations

5. Conclusion

This work has used the Field Anomaly Relaxation Method to develop a robust set of sectors and factors that can be used to describe the urban environment and in the generation of a plausible set of urban states. An analysis of the combined data from the three workshops (which gave similar results) gave the sectors Societal Behaviour, Urban Security, Governance, Societal Equity, Human and Physical Welfare and Economic Prosperity as the main drivers for urban societal function and population behaviour. Further analysis yielded 40 scenario clusters, corresponding to different urban environments. This data, in the form of the Faustian Tree, provides a simple, but useful high-level model of the urban environment. We have used it to evaluate urban centres based on the likelihood of stability/instability and have looked at possible migration paths between areas of lesser and greater instability within the Faustian Tree. Further work is needed to assess the utility of these predictions. Additional applications for these results range from urban scenario development, for wargaming, to a study of potential future urban evolution, for strategic planning.[22]

The conduct of the three workshops, and the results obtained, demonstrated the utility of FAR to the development of future urban states, with the problems encountered with the technique no greater than noted on previous occasions. [9] The use of subject matter experts in the third

[22] The military participant in the first FAR workshop was present in order to help inform future iterations of the Future Land Warfare Land Force capability development concept papers.

workshop also lent valuable credibility to the results, with there being no major differences between the outcomes of the three sessions.

While we have shown that the generated urban states correspond broadly to known cities and towns, further work may be necessary to validate, at least in part, the set of sectors and factors in terms of their appropriateness in describing current urban environments. Such work may also be useful in refining the data, especially in determining a more detailed subset of sectors and factors pertinent to those cities and towns identified in our model as likely to be less stable (and hence more likely areas of operation for the ADF). While it was initially necessary to consider the whole range of urban possibilities, and to identify pathways leading from stable to unstable environments, higher resolution models than the fairly generic ones presented here may be required. This would also better complement our work on historical population reactions in the AS region, which focus at a lower level (on riots, rebellions and revolts) [3-4]. A partial historical validation of the Faustian Tree may also be of benefit, although as noted previously, individual urban environments are unlikely to have traversed significant fractions of the complete Faustian Tree, even over a considerable time period (except in the case of war, which was not explicitly covered by this model). In addition, the FAR method is intended to scope future possibilities, particularly scenarios from 'left-field', so that a complete validation would not necessarily be appropriate.

6. Acknowledgements

The author would like to thank all the participants of the three workshops, listed in Appendix B. Special thanks are given to Professor Charles Newton for helping to organise and facilitate the workshops, and for providing guidance on the analysis of the data.

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Appendix A: DSTO Workshop on Future Urban Environments: Brief to Participants

Prior to the workshops, all participants were given the following brief, which explains the Field Anomaly Relaxation Process, and gives some background to Task ARM 03/102, Urban Operations Studies in the Littoral Environment, and the purpose of the study.

THE FAR METHODOLOGY

THE GROUPSTORM APPROACH

PRE-WORKSHOP PREPARATORY ACTIVITIES

CONDUCT OF WORKSHOP

POST WORKSHOP ACTIVITIES

A.1. The Field Anomaly Relaxation Method

The FAR Methodology, proposed by Russell Rhyne in the 1970s, offers a structured approach to projecting alternative comparably plausible futures. The concept behind FAR, which originated from the social sciences, is that individuals, groups, even nations exist within 'fields' of interactions with other entities and events. For an individual a 'field' may include factors such as career choices, family relationships, or even the financial environment, whereas for a nation a field may include factors such as the economic prosperity, technological innovation, political situation, the stability of the region where it is located, or even the state of the environment. The FAR methodology differs from the conventional forecasting methods in that it deals with whole patterns rather than component variables, and therefore allows the possible tracing of multiple futures and how they may evolve. The objective of this approach is to describe a problem domain in terms of a complete field of several **descriptors** (also known as **sectors**). These descriptors would describe those major areas of change that could occur over a relevant time period, say 5 -10 years for an individual, or a time span of 15 – 30 years for a nation's strategic planning process.

Descriptors are portions of the overall field, each contributing to form a mental picture of a possible future. It is essential that these descriptors not only describe the present situation but are also judged to be the most appropriate to describe futures in a similar context. It has been found empirically that no more than seven descriptors should be identified, and no fewer than five.

To describe different varying futures, each descriptor should have a discrete number of levels or values. Researchers using the FAR methodology term these values as **states** (also known as

factors).[23] A state determines a specific level or condition of a descriptor. If one was considering, for example, a descriptor describing the economic climate of a nation or region, then the state could include states such as zero growth, negative growth, slow positive growth or rapid positive growth. The set of states of a descriptor should cover the total range of behaviours of that specific descriptor. Hence each future may be described by a set of states, one from each descriptor.

Similarly no more than about seven states for each descriptor should be considered.

To ensure that no bias is introduced in the order of selection, importance or priority of the descriptors, a memorable acronym or symbolic language is determined by rearranging characters, one character selected from each descriptor name.

With the descriptors as column titles and states as rows, a two dimensional matrix can be developed, which describes all derived futures. See example below. If seven descriptors each with seven states are chosen then there is a possibility of 823543 futures.

EXAMPLE

M	I	S	R	E	D
Military interests	**International influence**	**Social environment**	**Regional political climate**	**Economic situation**	**Domestic political climate**
Neutral	Supportive	Harmonious	Cohesive	Booming	Effective
Controlling	Neutral	Tolerance	Stable	Expanding	Stable
Destabilising	Destabilising	Intolerance	Confrontational	Stable	Weak
	Controlling	Social unrest	Unstable	Decline	Civil unrest
		Violence		Bankrupt	Anarchy

It becomes apparent that for some of the determined futures, there exists a pair of descriptor/states that would not plausibly coexist, creating an **anomaly**. From the matrix above, one may suggest that the combination of Social Environment/ Harmonious and Domestic political climate/Civil unrest could be an anomaly. Therefore the next phase of the FAR process is to remove these anomalies through a pairwise comparison of states across the

[23] The established literature uses the terms sector and factor. However, it was found that the workshop participants were more comfortable with the terms descriptor and state. While the workshops were conducted using the latter terms, this report has been written using sector and factor.

descriptors. In most cases this reduces the number of futures significantly - sometimes up to 90% are removed. This comparison can be based on a Yes/No decision or by using a scale, say from 0 to 4, where 0 corresponds to 'impossible to coexist' and where 4 corresponds to 'most definitely to coexist'. A cutoff can then be determined such as pairs judged 3 or 4 could be kept and the others removed.

The next step in the FAR process is to group or **cluster** futures together based on small differences between the state descriptions/levels. For example in the case regarding a descriptor describing the economic climate of a nation or region, it may be agreed to group futures that are described by the states 'zero growth' and 'slow positive growth' together in a cluster.

Amalgamating these futures into clusters of similar futures results in a manageable number of clusters, allows an analysis of the possible evolutionary paths or dependencies of these clusters to be conducted. This analysis leads to the development of a tree-like structure representation of possible links between the futures, called the **Faustian Tree**. The Faustian Tree provides the roadmap to alternate futures, some of which may be identified as end nodes within the tree.

These alternate futures provide the stimuli to develop possible future scenario characteristics. Narratives can then be generated, based on the clusters' descriptor/state descriptions, to describe plausible futures. These narratives can later be adapted and further developed with detail appropriate to the intended purpose for the scenarios be it strategic planning, modelling etc.

A.2. The Groupstorm Approach

The FAR methodology can be strongly supported by groupwork, in particular through group brainstorming. The group brainstorming of the descriptors, states, pairwise comparisons and development of the Faustian Tree has, in the past, resulted in a much broader understanding and development of credible scenarios by stakeholders.

The Groupstorm software has been developed at ADFA under a joint research task with DSTO, and is based on the Grouputer hardware. The Grouputer hardware consists of a multiplexer and twelve keyboards. Inputs from the different keyboards are buffered and downloaded to a PC. These inputs can be displayed simultaneously as 12 separate sub-windows within a Windows environment via a projection facility. This facilitates the discussion between participants in the session and also allows the issues discussed to be captured electronically via the keyboards.

The Groupstorm software has been developed to support:

- Simple group brainstorming to Microsoft Word,
- Group development of vision and mission statements including SWOT and stakeholder analysis,
- Group FAR developments, and
- SMART analysis.

All of the inputted data from the group sessions are recorded and stored as Word documents for easy editing, analysis and publication.

A.3. Pre-Workshop Preparatory Activities

It is generally accepted worldwide that the likelihood of urban military operations is increasing. There appear to be two main reasons for this. Firstly, demographic trends indicate that populations are migrating from rural to urban centres, and since urban precincts are focal points for economic, political and social activity, they are prime targets for forces attempting to influence national decision makers. Secondly, potential adversaries are aware that the many technological advantages possessed by modern military forces on the open battlefield are (at least) partly neutralised in cities and towns. In addition to these factors, the natural clutter and uncertainty created by such environments, particularly when occupied by non-combatants, create a number of dilemmas for even the most capable force. The urban environment is therefore an increasingly attractive proposition for non-conventional threats. While such phenomena have become widely recognised, no specific attempt has been made to characterise possible future urban situations in the AS region, and thereby construct a contextual basis for discussion of future AS regional urban operations.

In 2000 the Land Warfare Development Centre (LWDC) identified numerous deficiencies in Army's Urban Operations capability. LOD was tasked to assist Army in the development of both current and future capabilities by undertaking studies to elucidate specific urban issues, and by developing a knowledge base to enable contributions to AS urban development plans. To further assist in the development of urban operations knowledge LOD has identified the need to create a set of future regional urban states. These states can be used to develop scenarios, which in turn can be exploited to identify capability requirements and deficiencies.

The aim of the workshop is to provide a set of defendable future regional urban states categorized by a set of key descriptors. This work will be achieved in two main phases as follows.

A.3.1 Phase 1: Determination of possible urban states

Determination of possible future urban states may be achieved by application of Field Anomaly Relaxation (FAR) techniques, or an appropriate modification thereof. While FAR is often used to predict high level or global states, the application to development of urban states is plausible. Due to the critical nature of population factors in urban operations the descriptor states should relate to the human situation rather than the direct physical aspects.

The initial set of descriptor states *may* include the following:

Urban **P**opulation Disputes
Cooperation Between **U**rban Communities
Resources Relationship
Stability of Urban **G**overnment
Economic Perceptions
Strength of Security Forces

Through the workshop a set of descriptor states will be developed using Groupstorm and FAR.

A.3.2 Phase 2: Generation of scenarios based on possible states

In this phase the outcome of the workshop will be used to put 'meat on the bones' of 5-6 chosen states (e.g. most likely, most difficult). Each state will be expanded to create an 'example' scenario urban environment. This will include the political situation, economic state, population factors, urban environment issues etc, in line with the outcome of Phase 1.

The aim of this workshop is to provide data, through the FAR process, sufficient to enable the development of a Faustian Tree.

To enhance the outcomes of the workshop, all participants are strongly encouraged to ***think about the main drivers/descriptors and their associated levels/states*** that describe the present situation of urban environments.

Secondly to facilitate the progress of the workshop, each participant is asked to ***develop at least one possible urban future (20 - 30 years hence) of Australia's sphere of interest***. The Australian Defence Review 2000 (White Paper) offers guidance regarding the likely theatre of operations that Australian forces may deploy to in the foreseeable future.

> *'Our most immediate strategic interests are in the arc of islands stretching from Indonesia and East Timor through PNG to the islands of the Southwest Pacific.'*

In developing a possible urban future, participants are encouraged to use similar descriptors and states as for the present situation, document them and bring them to the workshop. The form of this documentation should take the form of a ***very short essay (approximately a page)*** describing that future and the main descriptors and associated states.

A.4. Conduct of Workshop

The workshop will consist of sessions that will address the different phases of the FAR process.

The first session will be a brief brainstorming session in which agreement will be sought as to the exact aim of the workshop (the field and context of the investigation) and at the same time expose participants to the Groupstorm system.

The second session will be to brainstorm the descriptors deemed appropriate to describe the present and future urban situations, in particular for the South-East Asian and Oceania regions. Reference will be made to the participants' pre-workshop deliberations and they will be used as triggers in the brainstorming activities. Also, brief descriptions of the descriptors will be agreed upon and documented.

The third session will be to brainstorm the states of each of the descriptors, and also develop brief descriptions of the states, so that they can be agreed upon and documented.

The fourth session will be dedicated to developing the symbolic language/acronym.

The fifth session will be dedicated to carrying out a complete pairwise comparison of the states/descriptors to remove all the perceived anomalies.

The sixth session will attempt to cluster the remaining futures into a reasonable set so that a Faustian tree can be constructed. Also the cluster representing the current situation will be agreed upon.

A.5. Post Workshop Activities

After the conduct of the workshop, the facilitator/consultant and DSTO staff will cluster successful configurations and generate the Faustian Tree. General trends and end-states will be identified.

END OF BRIEF

Appendix B: Workshop Participants

The facilitator (Charles Newton) and the sponsor (Ashley Stephens) were present at all three workshops. The sponsor actively participated in the first workshop, but only helped to facilitate the remaining two workshops. The listed DSTO divisions are those where the participants were working at the time.

Workshop 1.

Dr Sharon Boswell (Land Operations Division, DSTO)
Kevin Dean (Defence Systems Analysis Division, DSTO)
Maj John Stone (Future Land Warfare)
Dr Niem Tri (Land Operations Division, DSTO)
Mr Keith Lawson (Defence Systems Analysis Division, DSTO)
Dr Joanne Nicholson (Defence Systems Analysis Division, DSTO)

Workshop 2.

Dr Peter Dortmans (Land Operations Division)
Dr Wayne Hobbs (Land Operations Division)
Ms Patricia Dexter (Land Operations Division)
Mrs Jacqui Willans-Price (Information Networks Division, DSTO)
Mr Justin Fidock (Command & Control Division, DSTO)
Dr Nick Beagley (Land Operations Division, DSTO)
Mr John Hall (Land Operations Division, DSTO)

Workshop 3.

Professor Riaz Hassan (Department of Sociology, Flinders University)
Professor Dean Forbes (School of Geography, Population and Environmental Management, Flinders University)
Associate Professor My-Van Tran (School of International Studies, University of South Australia)
Dr. Elizabeth Morrell (School of Political and International Studies, Flinders University)
Dr Andrew Allan (School of Geoinformatics, Planning and Building, University of South Australia)
Dr Suresh Dua (Land Operations Division, DSTO)
Dr Neville Curtis (Land Operations Division, DSTO)

Appendix C: Indicative Transition Probabilities

Table 23. Indicative transition probabilities derived from Equation 2

From	To	Transition S_{ij}	P	Rating	From	To	Transition S_{ij}	P	Rating
1	2	E12	0.14	VL	C8	C10	G23	0.42	M
1	3	H12	0.14	VL	C8	C12	U23	0.45	M
2	1	E21	0.76	H	23	15	B21	0.00	VL
2	4	H12	0.30	L	23	17	G32	0.72	H
3	1	H21	0.85	VH	23	24	H23	0.37	L
3	4	E12	0.25	L	23	26	S23	0.38	L
3	5	S12	0.27	L	23	35	U23	0.39	L
3	7	G12	0.25	L	24	18	G32	0.61	H
4	2	H21	0.68	H	24	23	H32	0.61	H
4	3	E21	0.65	H	24	25	E23	0.50	M
4	6	S12	0.40	M	24	27	S23	0.51	M
4	8	G12	0.40	M	24	36	U23	0.49	M
C1	C2	S12	0.34	L	25	19	G32	0.45	M
C1	C3	G12	0.33	L	25	24	E32	0.40	M
5	3	S21	0.71	H	25	28	S23	0.64	H
5	6	E12	0.34	L	25	37	U23	0.62	H
5	9	G12	0.35	L	C9	C7	G32	0.59	M
5	11	U12	0.35	L	C9	C10	S23	0.51	M
6	4	S21	0.58	M	C9	C13	U23	0.50	M
6	5	E21	0.56	M	26	20	G32	0.62	H
6	10	G12	0.50	M	26	23	S32	0.60	H
6	12	U12	0.49	M	26	27	H23	0.49	M
C2	C1	S21	0.65	H	26	38	U23	0.50	M
C2	C4	G12	0.42	M	27	21	G32	0.51	M
C2	C5	U12	0.42	M	27	24	S32	0.47	M
7	3	G21	0.67	H	27	26	H32	0.50	M
7	8	E12	0.45	M	27	28	E23	0.58	M
7	9	S12	0.44	M	27	39	U23	0.60	H
8	4	G21	0.52	M	28	22	G32	0.35	L
8	7	E21	0.45	M	28	25	S32	0.34	L
8	10	S12	0.56	M	28	27	E32	0.32	L
C3	C1	G21	0.60	H	28	40	U23	0.74	H
C3	C4	S12	0.50	M	C10	C8	G32	0.49	M
9	5	G21	0.57	M	C10	C9	S32	0.47	M
9	7	S21	0.55	M	C10	C14	U23	0.62	H
9	10	E12	0.53	M	29	17	U32	0.74	H
9	13	U12	0.52	M	29	30	H23	0.33	L
10	6	G21	0.42	M	29	32	S23	0.34	L
10	8	S21	0.42	M	29	35	G23	0.35	L
10	9	E21	0.37	L	30	18	U32	0.64	H
10	14	U12	0.65	H	30	29	H32	0.65	H
C4	C2	G21	0.50	M	30	31	E23	0.44	M
C4	C3	S21	0.48	M	30	33	S23	0.48	M
C4	C6	U12	0.59	M	30	36	G23	0.46	M
11	5	U21	0.61	H	31	19	U32	0.50	M
11	12	E12	0.46	M	31	30	E32	0.46	M
11	13	G12	0.50	M	31	34	S23	0.60	H
12	6	U21	0.47	M	31	37	G23	0.62	H
12	11	E21	0.44	M	C11	C7	U32	0.63	H
12	14	G12	0.65	H	C11	C12	S23	0.47	M
C5	C2	U21	0.54	M	C11	C13	G23	0.48	M
C5	C6	G12	0.58	M	32	20	U32	0.62	H
13	9	U21	0.45	M	32	29	S32	0.64	H
13	11	G21	0.42	M	32	33	H23	0.45	M
13	14	E12	0.65	H	32	38	G23	0.45	M

From	To	Transition S_{ij}	P	Rating	From	To	Transition S_{ij}	P	Rating
13	16	B12	0.74	H	33	21	U32	0.52	M
14	10	U21	0.31	L	33	30	S32	0.50	M
14	12	G21	0.26	L	33	32	H32	0.53	M
14	13	E21	0.25	L	33	34	E23	0.52	M
14	15	G23	0.01	VL	33	39	G23	0.56	M
14	17	B12	0.86	VH	34	22	U32	0.39	L
C6	C4	U21	0.38	L	34	31	S32	0.38	L
C6	C5	G21	0.34	L	34	33	E32	0.38	L
15	14	G32	0.91	VH	34	40	G23	0.72	H
15	23	B12	1.00	VH	C12	C8	U32	0.51	M
16	13	B21	0.26	L	C12	C11	S32	0.51	M
16	17	E12	0.76	H	C12	C14	G23	0.58	M
17	14	B21	0.14	VL	35	23	U32	0.58	M
17	16	E21	0.14	VL	35	29	G32	0.56	M
17	18	H23	0.20	VL	35	36	H23	0.50	M
17	20	S23	0.21	L	35	38	S23	0.50	M
17	23	G23	0.20	L	36	24	U32	0.48	M
17	29	U23	0.22	L	36	30	G32	0.45	M
18	17	H32	0.79	H	36	35	H32	0.48	M
18	19	E23	0.31	L	36	37	E23	0.63	H
18	21	S23	0.35	L	36	39	S23	0.64	H
18	24	G23	0.31	L	37	25	U32	0.34	L
18	30	U23	0.32	L	37	31	G32	0.30	L
19	18	E32	0.59	M	37	36	E32	0.27	L
19	22	S23	0.48	M	37	40	S23	0.77	H
19	25	G23	0.46	M	C13	C9	U32	0.47	M
19	31	U23	0.46	M	C13	C11	G32	0.44	M
C7	C8	S23	0.35	L	C13	C14	U23	0.64	H
C7	C9	G23	0.32	L	38	26	U32	0.46	M
C7	C11	U23	0.33	L	38	32	G32	0.46	M
20	17	S32	0.77	H	38	35	S32	0.48	M
20	21	H23	0.31	L	38	39	H23	0.62	H
20	26	G23	0.30	L	39	27	U32	0.36	L
20	32	U23	0.34	L	39	33	G32	0.35	L
21	18	S32	0.63	H	39	36	S32	0.34	L
21	20	H32	0.67	H	39	38	H32	0.36	L
21	22	E23	0.39	L	39	40	E23	0.71	H
21	27	G23	0.41	M	40	28	U32	0.22	L
21	33	U23	0.44	M	40	34	G32	0.20	L
22	19	S32	0.50	M	40	37	S32	0.21	L
22	21	E32	0.51	M	40	39	E32	0.19	VL
22	28	G23	0.56	M	C14	C10	U32	0.35	L
22	34	U23	0.58	M	C14	C12	G32	0.34	L
C8	C7	S32	0.63	H	C14	C13	S32	0.34	L

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Ashley KW Stephens

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Future Urban States: a Field Anomaly Relaxation Study

3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)

Document (U)
Title (U)
Abstract (U)

4. AUTHOR

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5. CORPORATE AUTHOR

DSTO Defence Science and Technology Organisation
PO Box 1500
Edinburgh South Australia 5111 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TR-1910	AR 013-732	Technical Report	August 2006

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
2005/1055054	ARM 03/102	COMD LWDC	56	21

13. URL on the World Wide Web

http://www.dsto.defence.gov.au/corporate/reports/DSTO-TR-1910.pdf

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Chief, Land Operations Division

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19. ABSTRACT

The Field Anomaly Relaxation Method (FAR) has been used to derive a set of plausible future urban states. The data was obtained from three two-day workshops involving DSTO staff, military, and academic staff from South Australian universities. An analysis of the results of these workshops identified six key sectors for urban function (each with three generic factors or levels) that could be used to characterise current and future urban environments namely: social behaviour, urban security, governance, societal equity, human and physical welfare and economic prosperity. From this data, 40 possible urban configurations were derived, which were further grouped into 16 scenario clusters. A Faustian Tree was constructed showing possible transitions between the future urban scenarios. The tree clearly broke down into two distinct areas, depending on whether the social behaviour was in a state of tolerant co-existence or intolerant co-existence/societal breakdown. A simple analysis was conducted to evaluate each cluster in terms of urban stability and hence identify urban precincts of interest. The relative probability of different migration pathways between urban states within the Faustian Tree was also investigated. The data generated in this study provides a simple high-level model of the urban environment, with potential applications ranging from urban scenario development (for wargaming) to a study of potential urban evolution (for strategic planning).